AUTOMOBILE REPAIRING MALE EASY

SHOP METHODS EQUIPMENT PROCESSES

BY

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PREFACE

The rapid growth of the automobile industry has resulted in a marked increase in the number of automobile repair shops and, as the sale of cars augments yearly, the demand for mechanics skilled in the art of caring for, adjusting and repairing automobiles will continue to grow in proportion. Then again, many cars are purchased by people in moderate circumstances or others remote from repair shops who desire to make their own adjustments and minor repairs. Many excellent mechanics in other lines have felt that the automobile business offered opportunities, but were unable to avail themselves of them because of lack of knowledge of motor car construction.

The writer obtained much practical knowledge of automobile mechanism first hand as a repairman in the earlier days of the automobile industry and often felt the lack of definite, scientific instructions for doing various classes of work in a practical manner. When one considers that the modern automobile is a complex assembly of many different groups, it is not difficult to understand why an excellent machinist, for instance, may be unable to repair a starting and lighting system because of lack of electrical knowledge, or why the electrician, to whom this work is not difficult, may be unable to refit bearings or time a motor valve system. The practical all-around automobile repairman must not only understand machine work and metal-working tools of all kinds, but must also possess some of the knowledge of the electrician, plumber, wood-worker, rubber-worker, tinsmith and blacksmith.

It is the purpose of the writer to outline the essentials of automobile repairing in a way that will be understood by all with ordinary mechanical ability. Much of the material will prove of equal value to the chauffeur, owner and general mechanic. The writer has been collecting notes and sketches for this treatise for over eleven years and has had an exceptional opportunity to sup-

plement the practical knowledge obtained as a repairman by a careful observation of the experiences of others.

With the object of outlining the entire subject, the various items of equipment, tools and special appliances to facilitate repair work are covered fully and a concise review of the various mechanical processes, such as autogenous welding, brazing, soldering, etc., is given as well. Many Tables and Formulæ are included pertaining to things the repairman should know or have available for ready reference. Special attention has been given to the electrical system, because it is on this point that many repairmen and motorists desire enlightenment. It is assumed that the reader is familiar to a certain extent with automobile construction in general. If information is wanted on points of design, etc., the reader is referred to "The Modern Gasoline Automobile," a previous work of the writer.

As many establishments are being started from time to time to care for the increasing number of motor vehicles sold, some suggestions for planning and equipping various sized shops should be timely and of value to those intending to start such an enterprise. There are many conditions to be considered, and no hard or fast rule can be made to cover all contingencies. The equipment needed to do work in a most satisfactory manner will vary with the size of the shop and character of cars repaired. The writer will confine this discussion to useful suggestions that can be applied specifically to the machine or other shop that specializes in repair work.

Most of those outlined have no facilities for doing a garage or storage business, but the plans may be modified and applied to shops operated in connection with a garage or agency for cars as well. While the equipment proposed is most comprehensive in the case of the larger establishment and sufficient to build all parts of a motor car if necessary, the facilities may be increased or reduced as the capacity of the shop requires. In planning a new shop or enlarging a business, some of these suggestions may be of value, and it is well to note that proposals made for tools or equipment and floor plans described are based on actual experience of successful shops.

THE AUTHOR.

November, 1912.

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AUTOMOBILE REPAIRING MADE EASY

CHAPTER I

THE AUTOMOBILE REPAIR SHOP

Requirements of Buildings Utilized—Lighting Methods—Heating and Ventilation—Arrangement of Departments—How Raw and Finished Stock Is Stored—Planning Small Shop—Arrangement of Medium Size Shop—Typical Large Service Station—Assembling Room Equipment—Bench Construction—Bench Furniture—Assembling Room Furniture—Pit Construction—Turn Tables—Lifting and Moving Appliances—Machinery Equipment for Small Shops—Equipment for Complete Machine Shop—Power for the Shop—Electric Power—Small Generating Sets—The Gas and Gasoline Engine—Power Needed for Various Machine Tools—Installation of Machine Tools—The Lathe Types and Accessories—Shapers, Planers and Drilling Machinery—Miscellaneous Appliances—Air Compressor Equipment—Fuel Storage Methods—Shop Forge Equipment.

The care and maintenance of automobiles is one of the most important branches of this large industry and as great advances have been made in the erection and equipment of establishments for repairing these vehicles as in the design of the automobiles. The equipment of a service station will vary from a very simple tool outfit of the small shop mechanic to the more expensive installation found in metropolitan service stations. Many special appliances have been evolved, especially for automobile repairing and special tools and fixtures have been contrived by the ingenious mechanic to simplify repair work. Before describing the processes incidental to the repair of the various motor car components the writer believes that a discussion of the equipment needed for repairing will prove of value to those who are about to erect an automobile repair shop or service station, as well as to those who plan to increase present more or less limited facilities. Several

important points that are apt to be neglected by the average architect in designing a garage or repair shop building will be considered first and then the equipment of tools, supplies, and special appliances necessary to furnish the repair shop in a first class manner will be discussed.

Requirements of Buildings Utilized.—Structures that have been used in another business do not always give full satisfaction when remodelled and equipped for motor car repairing. The one general fault all of these buildings have is inadequate lighting facilities, and they are seldom properly heated or ventilated. Large wooden structures formerly used for carriage or wagon shops, livery stables, etc., are often utilized, but these are invariably very inflammable, which alone should condemn them, even if the proper lighting and heating facilities were installed.

Many buildings have been erected for repair shops or garages that are lacking in conveniences not included because of lack of experience on the part of architects or builders, who do not understand the requirements of the repair business. These buildings obviously could be improved in arrangement and even in details of construction by those familiar with the restoration of automobiles and their component parts.

Any structure used for motor car housing or in repair work should be absolutely fireproof, which means that only materials having the desired qualities, such as steel, brick, stone or concrete be incorporated in the construction, with a minimum of wood. The building should not be more than two stories high, if the land is available, though large establishments in the heart of big cities will have to be three, four or five stories in height, depending upon the size of the lot available, the floor space needed and the prevailing prices of real estate. If it is to be operated in connection with a garage business on the same premises, the repair shop should be in the second story, the storage room on the ground floor.

In any event, the point of using natural to the exclusion of artificial light cannot be too firmly impressed on the builder. Mechanical work of all kinds demands the best of light, and in those buildings utilizing daylight in preference to electricity or other source of illumination, not only is the work carried out better,

but a large item of expense, which must be included in the fixed charges of operation, is eliminated. The best construction, and one that has been demonstrated to be thoroughly practical in large modern manufacturing establishments, is a steel framework, with concrete walls pierced by many large windows, and a sawtooth roof. The advantages of this construction over that using ordinary skylights is that the sun cannot shine in directly to interfere with the work, as the openings point toward the north, a stronger roof having more openings for light is obtained, and there is no possibility of water leaking in. What is most important in the northern states, the light will not be shut out as much by snow during the winter.

It is well to remember when planning large shops having more than two floors that high structures involve the use of power elevators, so the cars can be taken from one floor to the other, with increased overhead expense as it augments the cost of handling cars either in repair work or storage for which no charge can be made the patron.

Lighting Methods.—The lighting problem can be viewed from two aspects: that of general illumination and the equally important one of individual lighting. For the former, powerful, though well diffused lights are wanted, these being placed high enough so they will be out of the way and yet give as much as possible the general effect of daylight. The amount of illumination needed varies with the different departments and the class of work carried on therein, but in making determinations it is always best to err on the excess side than to attempt to economize at the expense of the eyes of the workman. This is poor economy because it reacts directly upon the quality of the work turned out by the shop. In the car assembling or overhauling department, the general illumination should approximate about 120 candle power to every 200 square feet, while in a regular shop or room where the general lighting means is supplemented by individual lamps at vises and drop lights to carry to the cars themselves, the allowance of 100 candle power of general illumination to 300 square feet floor area will be found ample. Machine shop lighting should always be on a very liberal scale and should not only include good general illu-

mination but individual lighting as well. The general practice in most shops is to use small units and plenty of them. Thirty-two to sixty-four candle power lamps or other equivalent radiants are suspended over each machine tool where great accuracy of work is not essential, these including such appliances as shapers, planers, emery wheels, arbor presses, drilling machines, etc. On lathes, milling machines or grinders, where accurate cuts must be taken, the individual lamps should be supplemented by arc lights or powerful Tungsten lamp clusters, supported from the ceiling and well shaded to reflect the light where it is needed. One candle power per square foot floor area in addition to the individual lights, which should be at least 50 candle power over each tool designed for accurate work should be allowed in the machine shop.

Where electric current is available the most suitable lamp from the viewpoint of steadiness, quality, and intensity of light is the incandescent filament lamp using the Tungsten alloy illuminating element. The flaming arc is an economical light, but it is far from being steady and its color is such that it is hard to discover fine lines or colors having a bluish tinge. The fluctuation in an arc light and even the clicking of the regulating mechanism may become very annoying when engaged in fine work. Many garage and repair shop proprietors in small towns where there is no central lighting plant find it desirable and economical to generate their own current by any one of the many small individual lighting units sold for this purpose using a gas or gasoline engine as power. The electric current reduces the fire risk and as it is the most convenient form of energy for generating power to operate machine tools, the installation of individual lighting plants is justified by the many advantages accruing from the use of electric current.

Where electricity is not available it is rarely possible to find either coal or water gas such as generated by a public service corporation. In many small, isolated communities it may be necessary to use acetylene gas generated on the premises. Some favor kerosene or gasoline vapor lamps in which incandescent mantles are employed. One popular lamp in the rural sections which burns oil under air pressure producing a Bunsen flame capable of heating the usual incandescent thorium mantle is called the "Washing-

ton" lamp and is a very economical method of lighting. It is apparent that any system of illumination that involves the use of a naked flame introduces an item of fire risk that is very undesirable in a building where the fumes of gasoline are present.

Electricity is not only the safest method of lighting but the Tungsten lamp is the nearest to sunlight of the artificial radiants. Where electricity is available it will be poor economy to use other means of lighting, except for general illumination as by groups of incandescent mantle gas lamps. For individual lighting the electric lamp is the most suitable because it is safe, compact, clean, does not give out much heat, is portable and can be used in any position. There is no other means of artificial lighting that permits one to obtain all of these desirable requirements in combination. Considering the relative cost of the various methods of lighting, the following table, based on the cost per 100 normal candle hours, will prove useful:

	Cents
Washington light	0.238
Flaming electric arc	0.381
Mercury vapor lamp	0.595
Incandescent gas light	0.595
Incandescent petroleum light	0.714
Direct current electric arc	0.942
Osram, zircon and tungsten lamp	1.190
Kerosene burner	1.666

The writer has frequently noticed the use of poor droplights in garages which are not only undesirable because of the physical discomfort entailed by the action of the electric current upon the human system, but also because of the liability of fire. The wire and sockets of these lamps are subjected to very severe treatment and they soon cause trouble where a cheap equipment has been provided, because the insulation of the wire deteriorates and will cause a short circuit whenever it comes in contact with the metal part of the frame or of the various parts of the human system which will provide a path to the ground for the current. Where a current of 110 volts is used, there is no danger of severe or permanent injuries because of contact with such a "live wire," but the sensation is decidedly unpleasant, to say the least. Cases have

been observed by the writer where a fire has been caused because of such defective insulation of the wire. One case in particular has been distinctly impressed on his mind because he was in a pit beneath a car at the time of the fire. A helper was washing the mechanism with gasoline, preparatory to an overhauling, and plenty of vapor filled the air. A partly bare spot on one of the wires became crossed with the frame work of the car and the brilliant spark resulting ignited the gasoline immediately. The car and pit were in flames and had it not been for the presence of mind of another mechanic with a chemical extinguisher in dealing with the blaze before it assumed dangerous proportions, the results might have been more serious.

In figuring on a droplight equipment, the best material should be obtained. It is a "penny wise, pound foolish" policy to use materials for which the only recommendation is cheapness. The wire should be provided with a very heavy insulation, and need not be very flexible. Beware of lamp cord, as it is of no value for use under severe conditions. The best and heaviest sockets should be used. The writer would advise the use of some that had either a very heavy porcelain or hard rubber insulation around them. Then comes the choice of proper cages or shields and handles. There are cages now marketed that are of heavy construction, the wire of which they are composed being nearly an eighth of an inch in diameter. These will prove to be the cheapest in the end. In assembling, it will be found best to wind plenty of electrical tape around the wires for the entire length of the drop. This not only serves as an additional insulator, but takes much of the wear that would otherwise come upon the insulation of the wire proper, and it may be easily renewed when it shows signs of wear. It will be found well to solder all the connections at the socket and rosette, as there is nothing more disconcerting, when a difficult or tedious job of fitting or adjusting is being performed, than to have a "winking" light to work with, which is liable to fail at the time it is needed most.

Heating and Ventilation.—It is very important that the workrooms should be kept at comfortable temperature during cold weather. About 75 degrees Fahrenheit is usually considered correct,

though it may be lower than this if the men are engaged in active labor. In the machine shop where men must stand quiet much of the time, the temperature should be higher than in the erecting room, where they are constantly moving around and handling parts, this tending to keep the blood in circulation. It is a mistaken idea on the part of some shop managers that the men must be half frozen so they will exert themselves more than if conditions were more favorable to comfort.

This is true if the temperature is much too high, but there is little danger of this happening in a large shop having considerable metal to absorb heat, and where the doors are opened to admit cars many times each day. A man cannot work with any degree of accuracy if his fingers are numb. When shops are cold, the operatives compensate for this by wearing heavier extra clothing that hampers their movements appreciably. What is gained in fuel is lost in labor, to say nothing of the effect unfavorable conditions have on the dispositions of the workers.

Of the methods of heating in vogue, the writer unhesitatingly recommends steam or hot water, in connection with judiciously placed radiators and pipes. The amount of radiator surface needed should be computed very accurately, and can only be determined by taking into account the character of the walls, number of windows, cubical contents of the rooms to be heated, the facilities for ventilation, the number and size of doorways and many other conditions best considered by a competent heating and ventilating engineer. The steam or hot water boiler has the advantage of furnishing warm water at all times for washing purposes, and as the radiators may be shut off if too warm, the temperature can be regulated to suit requirements and to secure economical and efficient heating from the fuel burned.

The problem of ventilation is one that is of importance, though its character depends upon the type and construction of the buildings used. Repair shops are usually of large size, and have large space in proportion to the number of workmen employed. In many cases of ground floor shops, this ratio is so large that no special provision need be made, the air being changed often enough to answer all practical needs, as the main entrance is opened and

closed. With a number of upper floors, conditions are different and in such cases every endeavor should be made to renew at least one-tenth of the total contents every hour. In paint shops, smith, and testing or adjusting rooms where noxious fumes may be present, and in small rooms where the number of workmen is greatly in excess of the air space available, no less than half the contents should be renewed hourly. The suggestions for building, heating, lighting and ventilation apply to all shops.

Building Arrangement.—As an example of the amount of space allowed in a building devoted to both a garage and repair business

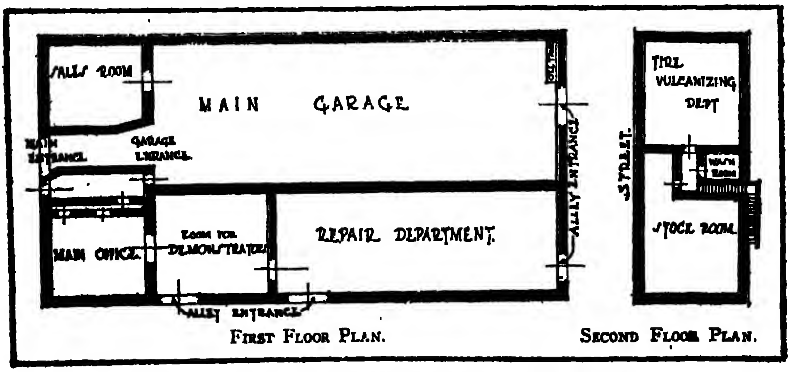


Fig. 1.—Floor Plans of Garage and Repair Shop.

the floor plans of a garage located in a city of forty thousand inhabitants is presented at Fig. 1. This building has a frontage of 74 feet and is 150 feet deep. The front faces a main street and is occupied by a sales room 30 feet square in one corner, and a main office of the same size in the other corner. The sales room has an attractive show window across the entire front, and the other departments are also liberally provided with windows. One side of the plant faces an alley extending the entire distance, and there is also an alley to the rear. This offers the important advantage of providing a situation on what is practically three well paved streets. The alley to the north is practically exclusive and affords the company a chance to store many cars during the day and at the same time leaves plenty of room for the vehicles to move.

around. The plant has five entrances, the main entrance at the front, which is 14 feet wide, two to the repair department, one at the rear to the main garage and one in the room set apart for the demonstrating car. All entrances measure 14 feet across and are amply high to permit the entrance of the largest motor truck. The building is of brick and concrete construction and is two stories

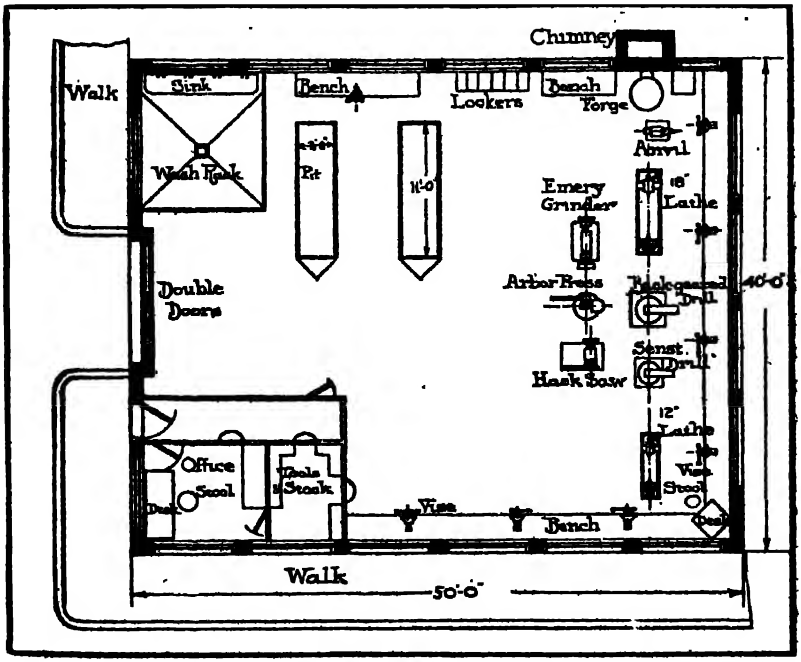


Fig. 2.—Floor Plan of Small Repair Shop, Showing Location of Pit and Machinery.

in height at the front. The second floor front is occupied by the tire repair department and the stock room. Skylights over the repair department and the garage proper furnish plenty of light from above.

The floor space on the main floor, back of the office and sales room is therefore divided into three sections. The repair department is 30 feet wide by 120 feet long and is situated to the rear of the office. The garage proper is to the rear of the show room

and is 44 feet wide and 120 feet long. The repair department is sufficiently large to employ 18 men. The building is heated by steam which is furnished by a heating plant in the basement underneath the main office.

The floor plan at Fig. 2 is that of a small building devoted exclusively to repair work and is suitable as a design for a shop to be placed at the side or rear of a garage. This building not only offers ample room to work on seven large cars but also provides for a complete machine tool equipment and ample space for office and stock room furniture. There is but one entrance, that being located at the front of the plant. The dimensions of the building and the arrangement of the various departments are so clearly shown that further comment is unnecessary. Floor plans are also given at Figs. 3 and 4 for a medium size service station, while a large departmentized repair shop is shown at Fig. 5. A medium size repair shop having a commendable arrangement of machinery and still leaving ample space for working on a good number of cars is shown at Fig. 6. In many large cities it is necessary to use buildings having more than one story on account of the value of land in business or manufacturing sections

A typical arrangement of a converted factory building that has worked out fairly well for a service station is shown at Fig. 5. This is operated exclusively as a repair shop and has complete facilities. The building is of brick and while not as well adapted for motor car repairing as the specially planned structure at Fig. 6 is, it has been remodelled to good advantage. The building is 165 feet long and 36 feet wide inside the walls. Considering that the building is an old one built before the days when the provision of ample light was considered one of the essentials, it is fairly well lighted during the day as the walls are pierced with many small windows. At night a large number of Tungsten lamp groups of high candle power furnish the general illumination. Both floors are divided into three rooms, the largest 104 feet long being used as an assembling and storage room on both floors. On the lower floor there is an intermediate room 28 feet long into which the elevator leads that is also used for assembling and overhauling purposes. The remaining small room on the ground floor which is 25 feet

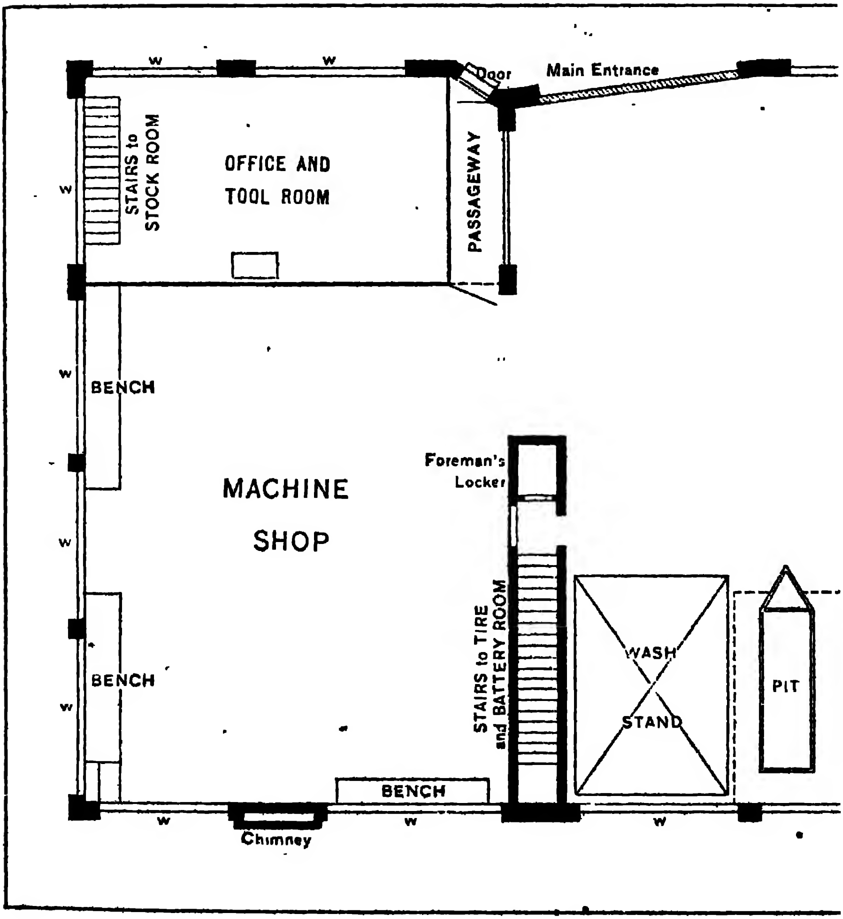

W
W
Door
Main Entrance
STAIRS to STOCK ROOM
OFFICE AND TOOL ROOM
PASSAGEWAY
W
W
BENCH
Foreman's Locker
MACHINE SHOP
W
STAIRS to TIRE and BATTERY ROOM
WASH STAND
PIT
BENCH
W
BENCH
W
Chimney
W
W

Fig.

long is divided into three parts, one being used for an office, the others for stock and tool rooms, respectively. Nine large pits are provided on this floor and there is also ample bench room. This ground floor assembly department is devoted to work that does not involve taking down a car to any extent such as fitting various accessories, tuning or adjusting engines, repairing clutches, brakes, axles, etc., and other work that will not lay up a car for more than a few days. There is a large door at one end to permit cars to enter directly from the street and a smaller entrance at the other leading directly into the passage way in front of the stock room counter over which the patrons are served. There is also a large door opening into the rear of the elevator, permitting cars to run on the elevator when this is in its lowest position, either from the shop interior or from the street.

The upper floor is divided in much the same manner as the lower one, the largest room being used for overhauling purposes, the 36 x 28 feet room is used as a machine shop, while the small room over the office and stock room is used as a forge and tinsmith shop. A large skylight in the roof of the blacksmith shop gives much needed light on the anvil and bench. There are no pits in this floor but, as is the case with the one below, there is an overhead track extending the full length of the room for travelling chain falls attached to the ceiling. The equipment of the machine shop is very complete and enough tools are provided so that it is possible to duplicate any part of any automobile. The equipment shown at Fig. 6 is also very complete.

In the building outlined at Fig. 6 which has been designed exclusively for automobile repair work it will be noticed that the saw tooth roof and the many windows make for maximum daylight illumination. The windows of the saw tooth should always face toward the north to get the best light and prevent annoyance due to the sun shining directly in during the day. The building may be of either brick or concrete and while the arrangement depicted is very good, the plan may be varied to suit individual requirements. It will be observed that there are two main entrances, one a small door, leading directly into the machine shop, while there is a large main door by which the cars enter the repair shop.

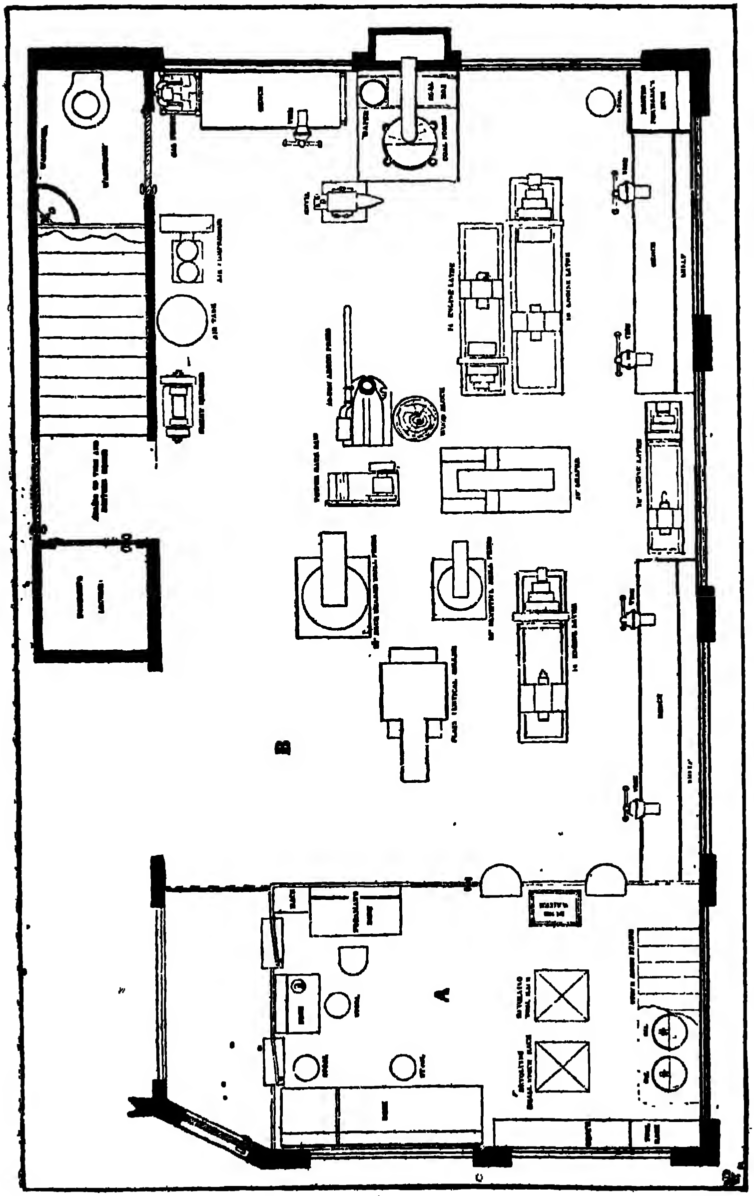


Fig. 4.—Plan of Automobile Repair Shop Machine Room, Showing Location of Machine Tools and Other Appliances.

It will be noted that the office is placed in such a way that all that goes on in either the machine shop or the assembling department may be seen by the executive or manager. The location of the stock and tool room in the machine shop is logical, as it is most convenient for the men who have frequent need of special tools. The men on the assembling floor usually have their own outfits, whereas the machinists are continually using special drills, taps, dies and cutters that the company must furnish. A person cannot enter the machine shop without first passing the clerk in either the office or the stock room, as wickets in the walls of these rooms forming the passageway open directly into the narrow hall providing access to the machine shop. A pair of large double doors separates the machine shop from the assemblying room as it is often necessary to move in bulky portions of automobiles for attention. In the building shown the boiler room is partitioned off from the assembly room and it is not intended to have any basement. If a cellar is provided, however, the heating boiler may be placed therein and be out of the way. The equipment of the various departments which can be applied to any of the repair shops shown will now be considered in connection with the logical arrangement of the repair shop department.

Arrangement of Departments.—In arranging the departments the layout should be for greatest efficiency and convenience. This applies to the repair shop as much as to the manufacturing plant. and intelligent study will often result in changes which will materially increase efficiency. Many shops are not profitable because of lack of organization and lack of system, while others are handicapped because of poor general arrangement. The owner or manager of a small shop may consider that the installation of a methodical system for record of the cost and progress of the work involves an expense that is unnecessary, and many shops are conducted by a hit or miss principle when simple accounting methods and organization of force would make them much more profitable. Too much system, however, is as bad as not enough, so a happy medium between the two extremes should be adopted. There should be some distinct scheme of organization in every shop of any size, especially in those which employ 18 or 20 men, and this can be advan-

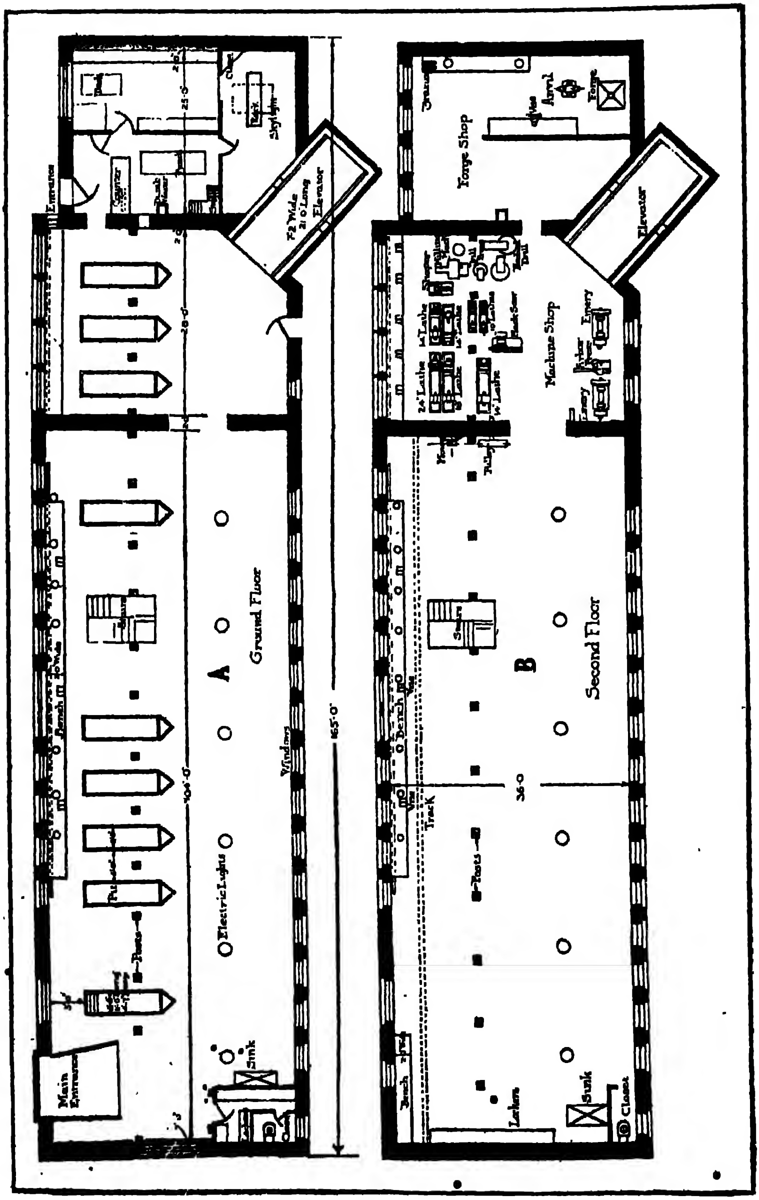


Fig. 5.—Floor Plans of Large Automobile Repair Shop or Service Station.

tageously followed where only five or six are employed, to the extent of properly apportioning the responsibility and authority.

The plan shown at Fig. 3, A, is a one-story structure with a two-story frontage, having a capacity for 30 cars. The building is about 120 feet long and 40 feet wide, divided into departments for convenience. The ground floor contains four departments. The front apartment is about 40 by 20 feet, which is again divided, the tool room and office being 10 feet wide by 16 feet long, the machine room about 30 feet wide and 20 feet long. The rear of the shop is partly divided by a partition extending about 15 feet from the right wall, and about 20 feet from the rear wall. The right back corner is partitioned by a brick wall into a room about 15 feet wide by 10 feet deep, this serving as the boiler room for the heating plant. The space between the front and back portions, about 80 feet, is used for general repairing, for taking cars apart and storing cars ready for delivery.

The ground floor has been divided into four parts—the tool room and office, the machine shop, the assembling bay and the overhauling room. The second story is about 25 feet deep and as shown at Fig. 3, B, is divided into three parts, a stock room with 15 feet frontage, a battery room 10 feet wide and a tire repair room the same size as the stock room. The entrance for cars is at the side of the building, and the door opens into the large room so the machines can be run directly back into the overhauling department, or ranged along the walls of the assembling room. A short passage leads from the small door at the side directly to the machine shop, though all entering must first pass the office before gaining admittance to the other departments. The plan shown can be applied only where the building is located at a corner, or where there is a short street or alley at either side. This form of construction permits one to take advantage of the whole front of the shop, and no space is sacrificed, as would be the result if the main entrance and passage were located at the front of the building.

An office and tool room are partitioned from the machine shop by sheathing and wire netting or grillwork, the wood of the partition being about four feet in height, all space above to the ceiling being filled by wide mesh net. Thus the tool room is effectually

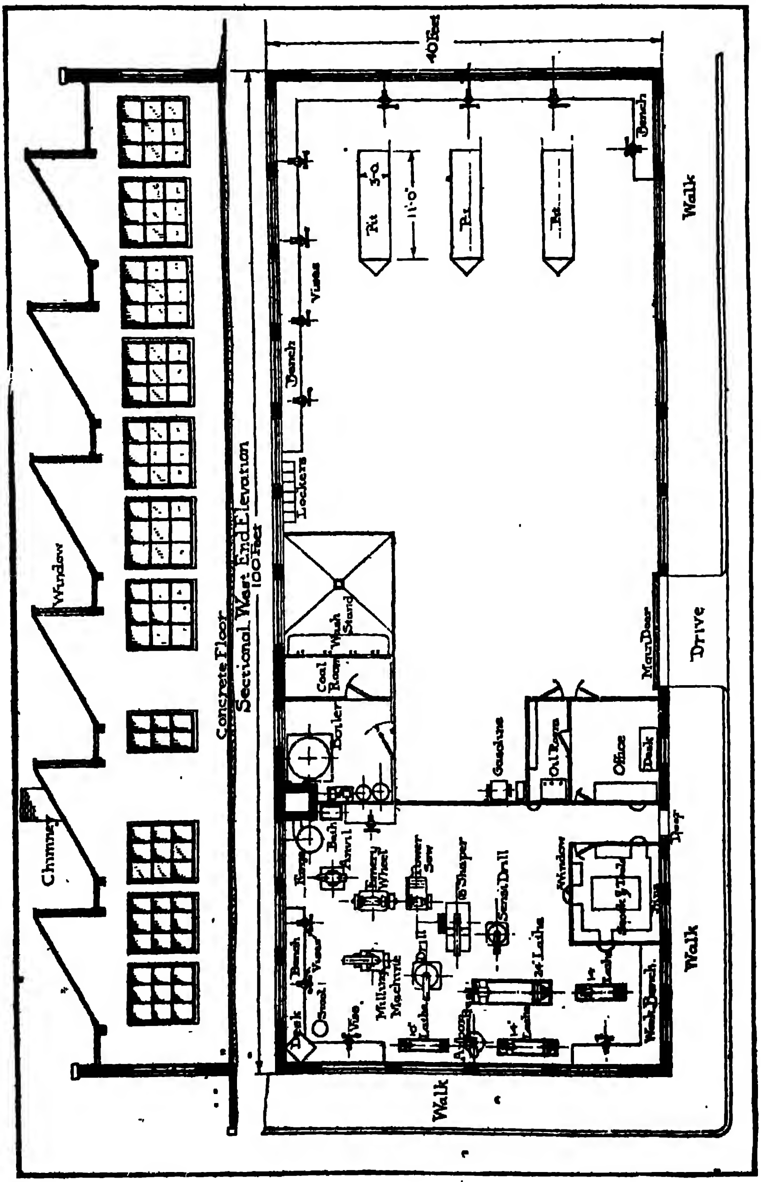


Fig. 6.—Elevation and Floor Plans of Medium Size Automobile Repair Shop.

separated from the machine room, and yet all that goes on in either room can be seen by the superintendent when in one room or the other. Two partially open partitions extend the width of the tool room, the one separating it from the passageway, the other from the machine shop. In each partition is placed two windows, closed by swinging screens. Along a portion of the side wall and under the stairs are tool racks, while many of the smaller and often-called-for tools, such as drills, taps, dies, reamers, etc., are carried on pyramidical revolving racks. These racks can also be used to advantage for nuts, bolts, machine screws, splitpins and other small stock often demanded.

The bookkeeper and clerk share a common desk ranged along the side wall, while the stenographer has a typewriter desk between the two windows communicating with the passageway from the street. This makes it possible for the stenographer to wait upon customers applying at either window. The one nearest the door permits a visitor to talk with either the clerk or bookkeeper, while that at the other side of the desk allows the caller to talk to the superintendent or manager, whose desk is conveniently placed so that he can look into the shop, keep his eye on the tools and stock, talk with either bookkeeper or clerk, or dictate a letter to the stenographer without leaving his chair. As no modern business is complete without telephone service, a single desk instrument with extension cord is placed on the stenographer's desk, and can be used by the superintendent, the bookkeeper or the clerk without leaving their work.

How Raw and Finished Stock Is Stored.—The arrangement and type of the racks can only be determined by the nature of the raw and finished material carried in stock. The stock room is directly over the office and tool room and a dumb waiter or small elevator as well as a stairway connects both floors. At Fig. 7, A, is shown a type of rack that can be used to advantage in storing small parts, this having lower bins of larger size for bulkier articles. At B is shown a combination rack for stock, both finished and rough, having a series of pigeonholes for tubing, bar steel and iron, etc., while the type at C permits one to store sheet stock as well as other and less bulky articles. A practical form of rack

for bar iron and steel, tubing, etc., is at D, this being a series of cast iron members joined by through bars, so coupled as to act as braces. A most practical form of rack for the repair shop stock-room would combine the forms shown at A, B and C, the bars and rods being put in from one end, the sheet metal, fibre, etc., being placed in the compartments at the other.

There is no need of mentioning the ways in which nuts, bolts, machine and wood screws can be best handled. Any stock man of experience would place these in revolving pyramidical racks, or

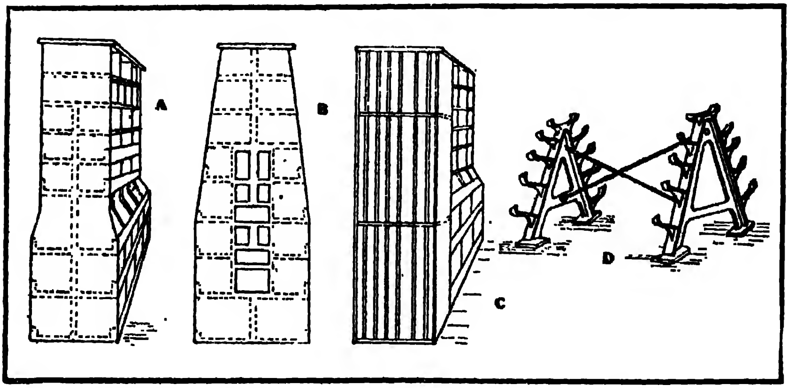


Fig. 7.—Bins and Racks for Storing Raw Material Used in Automobile Repair Work.

small cabinets where they can be easily reached, which permits of marking for ready identification. Wire, rubber hose, flexible copper and brass tubing, etc., need only be coiled and placed on convenient hooks; pipe fittings, gaskets, and small parts should be strung on wires and suspended from nails; sheet packings, rubber matting, etc., ought to be left on the roll, and mounted on stands so they can be easily unrolled.

A desk should be provided for the stock man convenient to the stairs and dumb-waiter or elevator. All smaller articles can be sent from one floor to the other by the elevator. The oil can be stored in the regulation pump-fitted tanks, while the grease can be kept in the original package if bought in bulk. These should

be stored in the tool room, as well as other stock that may be frequently called for. A good place for both oil and grease is under the stairs leading from the lower to the upper floor. A convenient storage place for waste is the interior of the revolving rack on which the smaller tools are placed.

In all well regulated shops there is a system of tool checking, all of the workmen being provided with small brass discs punched with a number by which the employee is known, one of these being surrendered to the tool boy for every piece taken from the tool room, and which is returned to the workman if the shop tool is surrendered in good condition. All broken tools should be immediately reported to the master mechanic or superintendent. No deviation should be made from the established rule, and no tool should go out of the tool room unless properly checked.

Every stockroom should have two weighing machines, an ordinary spring balance registering to 20 or 30 pounds and a platform scale so that all raw stock bought or sold by weight can be weighed before acceptance or delivery, and it will be found a distinct convenience to have a certain portion of shelf, table or wall measured off in feet and inches by which the length of wire, packing, etc., can be quickly determined without frequent search for a mislaid foot rule or yard stick. A card index and good stock numbering system will facilitate finding the location and price of any raw or finished material, and this can be best worked out as the actual conditions demand. If the repair shop management operates a garage and agency in connection, spare parts for the machines should be kept entirely separate, and in different racks or bins, and distinct from the raw material.

Lockers and Washroom.—The arrangement of lockers, washing and toilet facilities are shown by the floor plan. The washstand may be a long cast iron sink, or the more sanitary enamelled individual steel washbowl series placed in the market recently. Twenty places are enough, but all should have separate hot and cold water faucets, though they can discharge into a common pipe. The location near the heater simplifies the plumbing and provides hot water without delay or waste. The lockers should be about 18 inches square and six feet in height, having a shelf about a foot

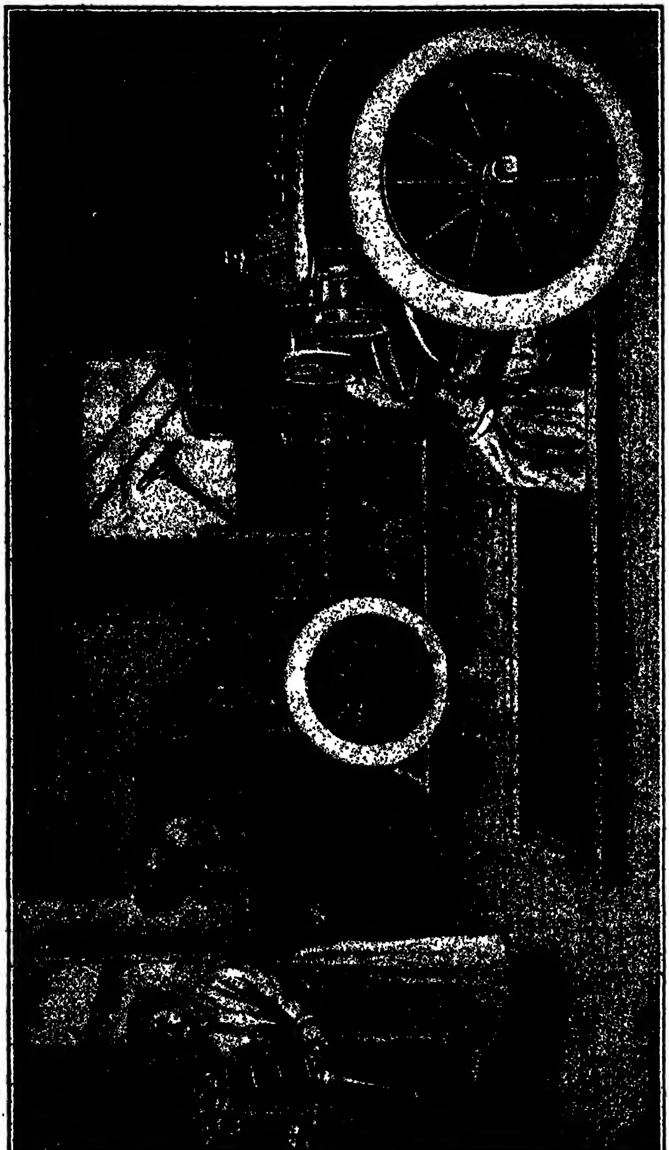


Fig. 8.—View of Shop, Showing Size of Pits and Relation to Work Bench.

from the top, and provided with hooks for clothes. The metal grillwork construction is to be preferred to the less sanitary wooden structures. All doors should be fitted with locks, and the workmen charged a nominal sum for the use of the key, to be forfeited if the key be lost. Two series of 10, placed back to back, are shown, another series for the overflow being ranged along the opposite side wall, or any other convenient place. The workmen regularly employed should be given the series nearest the sink, while the extra help may be assigned those available.

Assembling and Overhauling Departments.—Referring to the floor plan shown at Fig. 3, A, it will be seen the remainder of the building is divided into two parts, the larger room for light repairing, assembling and taking cars apart, and for storing cars awaiting attention or delivery, while the back room is used for overhauling. There is no close distinction drawn between the departments, however, and the same general class of work is carried on in either portion. The larger room has a cement floor, but over this is laid a wooden floor which runs along the walls, extending about 10 feet from either side. This room is provided with two pits as shown, and directly across the floor from the entrance is located the washstand, so that a car can be run in and cleaned without interfering with operations in the shop. The object of the wood floors or platforms is to keep the workmen from direct contact with the cement floor, especially in cold weather. The side on which the door is placed is used for storage, while at the opposite side is performed the work upon cars. To facilitate work and save time several short work benches, each provided with a vise, are ranged along the walls, so that workmen do not have to go to the front or back of the shop if bench work is necessary.

An overhead track and travelling chain and tackle make possible the lifting of the front or back end of a car, or carrying an engine, gearset or heavy object from the machine room clear to the back of the shop, or vice versa, without trouble. A useful adjunct is the travelling crane, shown at Fig. 18 in use, mounted on wheels, which can be taken from one part of the shop to another, and brought to the work instead of the work being taken to it, as is necessary with a fixed overhead track.

Construction of Shop Bench.—The machine or repair shop bench must be convenient to the machines, and ample space should be allowed for a person to pass between the workmen at bench and machine. Four good swivel vises and two surface plates, as well as a couple of small bench anvils will serve for a small shop. About five or six feet of bench room should be allowed between each vise. The bench will be about two feet wide, and 34 or 36 inches high. The legs can be made of iron pipe or castings, or of two by four inch scantling, while two inch planking across the top will form a backing for another covering of seven-eighths inch hardwood floor strips closely fitted together. The average machine shop bench of rough plank with gaping cracks along the top cannot be too strongly condemned, as not only is it difficult to work on the irregular surface, especially in laying out fine work, but many small parts will be lost by falling through the openings in the bench top of the floor. A strong shelf shou , placed on the wall about two feet above the bench for tools, stock, etc., when not in use, and a heavy shelf under the bench, about 18 inches from the floor, can be used to hold the odds and ends accumulated in a machine shop.

A very practical shop work bench may be constructed by using cast iron bench legs that may be obtained upon the open market as a foundation to which the timber and planking of which the bench is composed is attached. The approximate form of one o. these legs is shown at 1, Fig. 9, which also outlines the amount of space recommended between the bench and wall for heat to rise and to check window draft. This space, which should not be less than three inches wide will also allow water from the sprinklin system to reach any fire under the bench. The end view shows the usual method of building and the approximate size of th planking of which the bench is composed. The office of the cast iron leg is to make possible a stiff bench without depending on the walls for support, as is the case with the usual wooden sl bench.

It would be apparent that this construction lends itself ve well to various factory conditions as the bench is a unit structur when built up that may be changed from place to place witho

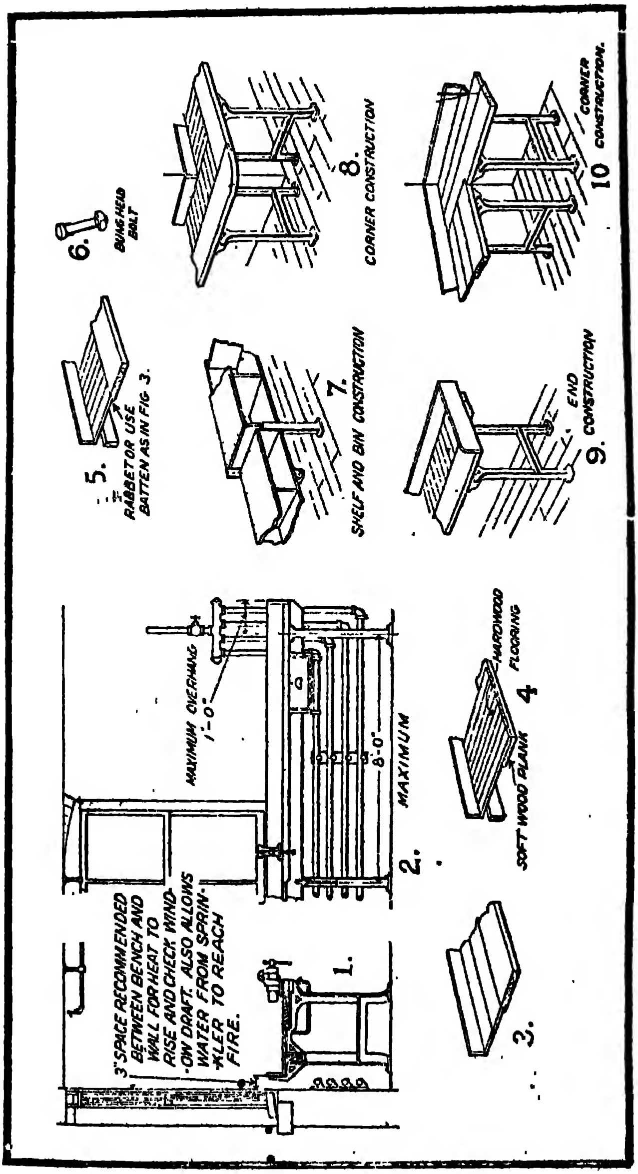


Fig. 9.—Methods of Constructing Shop Benches, Using Standard Cast Iron Bench Legs.

damage. The brace between the legs is just at the right height from the floor and is so built that it forms a basis for underneath shelf and bin construction, if desired. These bench legs are spaced not more than eight feet apart and the benches should have a maximum overhang of not more than one foot as shown at 2, Fig. 9. The views at 3 and 4 show the accepted method of arranging the planking. The system outlined at 4 in which hardwood matched flooring is used is a very satisfactory one, as there is no opportunity for loss of small parts through gaping cracks, such as exist in the usual hastily constructed shop benches. The method of using the bench legs for support of bins or drawers is clearly shown at 7, while two methods of corner construction are shown at 8 and 10. The former shows the usual practice in building the bench around a projecting corner while the latter demonstrates clearly the system used in filling a corner. The usual end construction is outlined at 9.

Bench Furniture.—The most important item of bench furniture is the machinist's vise outlined in section at Fig. 10, A. These are obtained in a variety of types adapted for the various mechanical trades. The vise for the automobile repair shop should have swivel jaws and should be capable of being set at various positions relative to the operator by means of a swivel base. The form shown in section is the simplest type and may be used for furnishing most of the bench space. Two or three of the cheaper simpler forms of vise may be used to each combination swiveling vise, as most of the work will be of a nature to which the simpler vise is adapted. The various forms of bench vises are clearly shown at Fig. 11. The Massey is a combined form adapted for pipe or straight work. The serrated angular jaw plates are set beneath the parallel jaws used for straight work. The Prentice device is the combination form that may be included with advantage in the equipment of all shops.. It will be observed that the back jaw is mounted in such a way that it may be swiveled to assume any desired angle when an irregularly shaped piece is to be held by lifting out the locking pin A which serves to keep the jaw in the parallel position when it is in place. In order to swing the entire vise around without loosening the anchorage plate it is necessary to lift the pin

B which keeps the upper and lower parts of the base in a fixed position.

Another form of bench vise that is of value when fitting small pieces is known as a die sinker's vise because of its almost universal use by mechanics of this class. This is carried by a base piece hav-

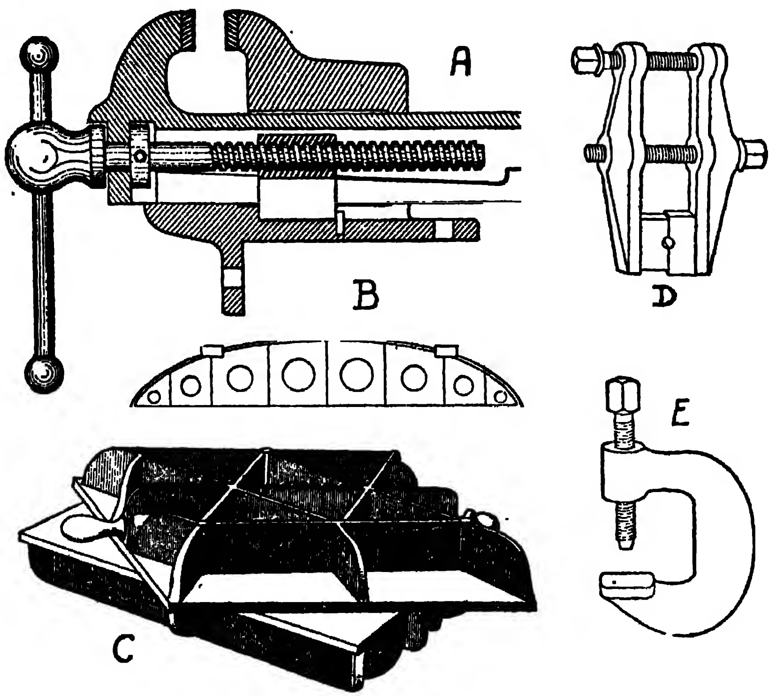


Fig. 10.—Some Indispensable Items of Bench Equipment.

ing a large ball formed at the lower end held firmly between a pair of jaws that may be tightly clamped by a hand-locking lever. As will be apparent the use of a ball and socket joint to hold the vise enables the operator to set his work in any one of a large number of positions. By releasing the clamp lever the ball is free in its socket and the vise may be set at any desired angle.

The Columbian pattern is the old stand-by of blacksmiths and

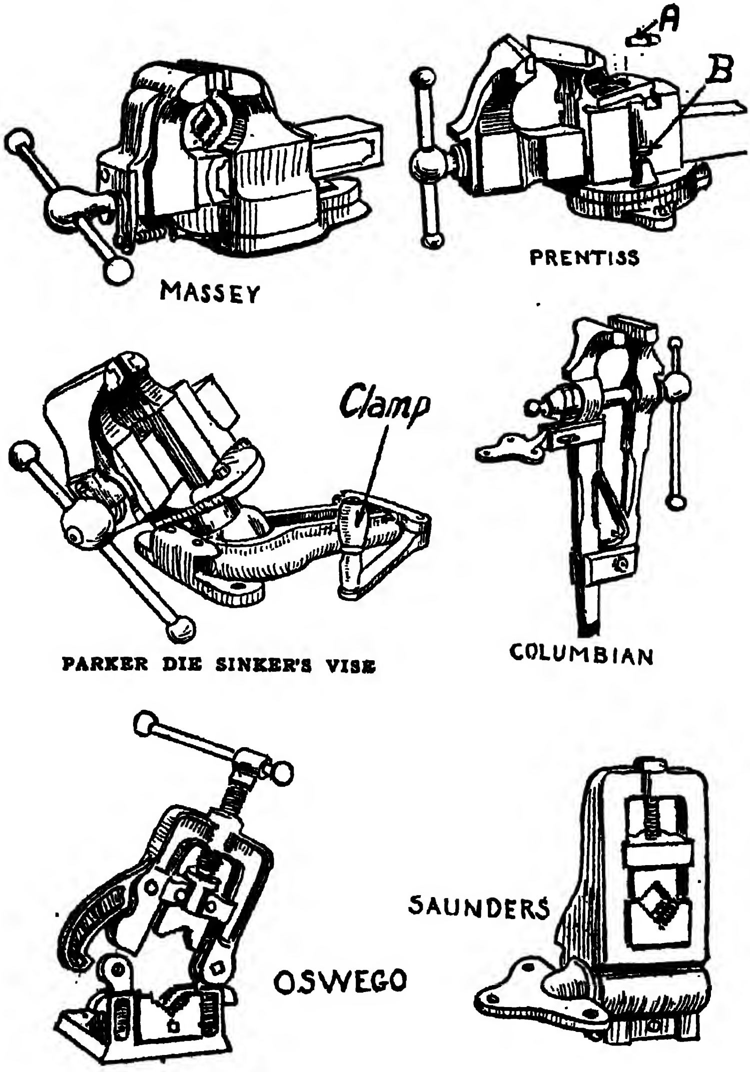


Fig. 11.—Types of Vises Adapted for Use in the Automobile Repair Shop.

wheelwrights, and as it is a form that is subjected to hard usage, the retaining clamp which is bolted to the bench in the customary manner is re-enforced by a heavy ball end supporting foot which rests on the floor. This form of vise is carried out further from the bench than the other types shown, because a blacksmith must handle long pieces of iron or steel and bend them at various angles.

The use of the pillar for supporting the vise structure is made necessary because the work is often subjected to heavy blows in the various smithing operations. The Columbian is usually included as forge equipment and is used at the blacksmith's bench.

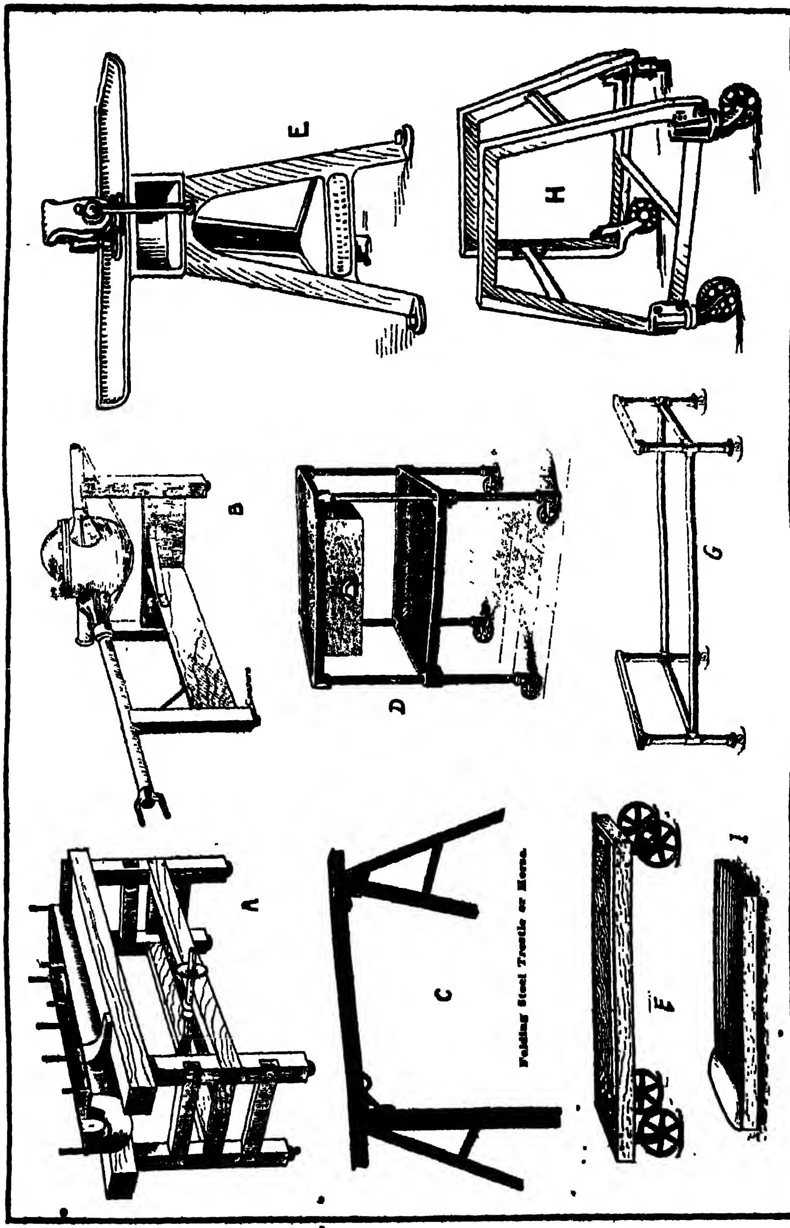
The Oswego and Saunders are forms of vises used only for holding pipes and rods. These employ toothed jaws which may be adjusted in the frame to accommodate various sizes of pipe. The Oswego vise frame is made in such a way that a long piece of pipe may be held by opening up the frame and slipping the pipe in place between the jaws through the opening provided. In the Saunders vise it is necessary to put the pipe in end first which may be inconvenient when long lengths of pipe having fittings on it is to be handled. Of those shown, three forms should be included in the equipment of every repair shop, these being the types represented by the Prentice, Columbian and Oswego.

Another item of bench equipment of value is the straight edge shown at Fig. 10, B. This is a very useful tool in the automobile repair shop, as it is widely used in testing alinement of the various units, straightness of frame members or tubes and for all purposes where comparison must be made with a perfectly true smooth and straight line. The form shown is made of cast iron of arch construction and with a perforated web in order to obtain maximum strength without too much weight. Another item of shop equipment is the surface plate which is shown at Fig. 10, C. These are made of cast iron, well ribbed at the back for rigidity and with the top surface planed accurately. A surface plate is used somewhat as a straight edge is and is a form of gauge very useful in determining flatness of surfaces. The bench equipment also should include a variety of metal hand clamps, two forms of which are shown at Fig. 10. The two screw type having parallel

jaws is shown at D, while a C clamp is outlined at E. Clamps are very useful in holding parts together temporarily that are to be fastened by some permanent means. They are useful adjuncts to the bench vise and have the added advantage that they can be moved when pieces are to be held against members that it would be difficult to hold in the vise. For example, in fastening various irons and braces to an automobile frame, the clamps are invaluable as a temporary means of keeping the members together while drilling for the permanent bolts is going on. Many of the repair operations to be described call for the use of clamps as shown.

Assembling Room Furniture.—There are a number of articles of equipment or furniture that are very useful on the assembling floor. That shown at Fig. 12, A, is a bench constructed of heavy timbers of such a form that it is well adapted to support automobile engines when these are removed from the car frame. A bench of this construction is also of value for supporting the various crank case components when work is being done on them that requires that they should be held level and securely. In the illustration a portion of a crank case is shown in such a position that work may be done upon the bearings. The simple supporting fixture shown at B is exceptionally useful for holding automobile rear axles. It is of approximately T form, being composed of two pieces of planks and three uprights well braced with iron bars and mounted on casters so the load may be moved with but little effort. The form of bench used and its actual construction will, of course, depend upon the type of axle that is to be supported. The member shown is intended for torque tube axles.

Another very useful piece of furniture is a trestle or horse such as shown at C which forms a good means of support for some of the parts when these are removed from the car chassis. A pair of these trestles should be included in the garage equipment as they can be used together to support a front or rear axle, engine, automobile frame and other bulky objects. The form outlined is a folding steel construction which occupies but little space when knocked down. It is strong, light, and fire-proof, all very good features in garage equipment. The workman engaged in floor work is often handicapped by not having some means of keeping



[illegible] Furniture for Use on the Assembling Floor.

tools and small parts off the floor when working away from the bench. The metal table shown at D is very well adapted for the individual workman's use, as it is provided with a drawer in which tools may be locked and also with a substantial metal top and shelf on which work may be done. The table is mounted on wheels and may be easily moved, even when loaded to capacity. Another useful adjunct to the assembling department equipment is shown at E. This is a cast iron bench having a vise attached and mounted on a tripod which offers a substantial foundation. There is a compartment immediately below the bench top for holding tools and a shelf above the floor that may be utilized for the same purpose. The table shown at D when fitted with a rack at the side and back is also well adapted for use in the forge room, as it will hold all of the blacksmith's tools and cannot be set afire by a piece of hot iron as a wooden bench is. The addition of the rack makes it possible to carry the assortment of tongs usually found at the forge.

Three forms of wheeled trucks are shown at F, G and H. That at F is a low framework that may be boarded over and used for conveying heavy parts from one end of the shop to the other or that can be used just as shown for conveying axles, engines and gear boxes which are of irregular form and which could not be conveniently carried by a platform. The truck shown at G is made of pipe fittings and is used for supporting automobile frames when the springs and axles have been removed. As this is provided with wheels it can be easily moved with its burden as desired. The cast iron stand at H was designed especially for handling transmission gear boxes in a service garage where one particular make of car was looked after exclusively. As designed it was only suitable for use with the gear box found in this car. By being slightly modified to the extent of having adjustable brace members joining the two sides it could be used to advantage for a variety of purposes. The small wheel truck shown at I is known as a "creeper" and serves to keep the workmen off the floor when working underneath a car. This is provided with a head rest at one end and it may be easily moved about without the workman using it getting up from his reclining position. These trucks are

sometimes provided with a shelf at one side to support tools and to insure that these will move whenever the operator does. The various pieces of furniture outlined will be susceptible to various changes that will adapt them to the specific work in hand, and a repair shop of any pretentions will be able to use all of the furniture shown to good advantage.

Construction and Size of Pits.—The back shop shown at Fig. 3, A, has two pits, and the arrangement of the work benches can be seen. At the end of the short bench placed against the boiler room wall is a pipe vise, while at regular intervals along the benches are placed strong swivel vises. This bench is 30 inches deep, about 36 inches high, of rough construction, and built very heavy to stand abuse. The pits are four and one-half feet deep, three and one-half feet wide and 11 feet long. They are lined with heavy planking, and stairs permit the workmen to descend and ascend without effort. Along the side walls of the pits and about two and one-half feet above the bottom, two pieces of two by four scantling are fastened, these to support a board that may be moved from one end of the pit to the other, as a seat for a workman. With more general use of the motor truck it will be well to install a larger and shallower pit, as the mechanisms of these vehicles are carried higher than in the conventional touring car. Such a pit should be about three and one-half feet deep, four feet wide and 14 feet long. The edges of all pits should be sharply defined by a surrounding frame of two by four scantling, this being a guard to prevent the wheels rolling into the pit while manœuvering a car about it.

The view at Fig. 8 shows the depth of the pit with an operator standing upright and also depicts clearly the frame work around the pit to guide the car wheels. The amount of space allowed between the edge of the pit and the workbench is also depicted. In some shops it is customary to have a pit cover made in sections so that when only one end of a car is to be worked on but a portion of the pit is used, the remainder being covered by one section of boarding to prevent the workmen at the bench from falling into the pit. In some shops the electric wiring is run to the pit interior and ends in a plug socket so that a drop light or extension cord may be connected without the necessity of having a long length of wire

trailing over the floor as is necessary when the connection is made to one of the lamp sockets over the bench.

Turn Tables, Lifting and Moving Appliances.—In many repair shops where the floor area is limited or where the floor space is broken up by a number of posts it is often difficult to move cars about even under their own power and it takes considerable maneuvering to head the car around in the other direction. The ideal solution of this problem is the turntable in its various forms. The simplest and cheapest is in the form of a small wheel truck as shown at Fig. 13, having the wheels mounted on a swivel carriage so they

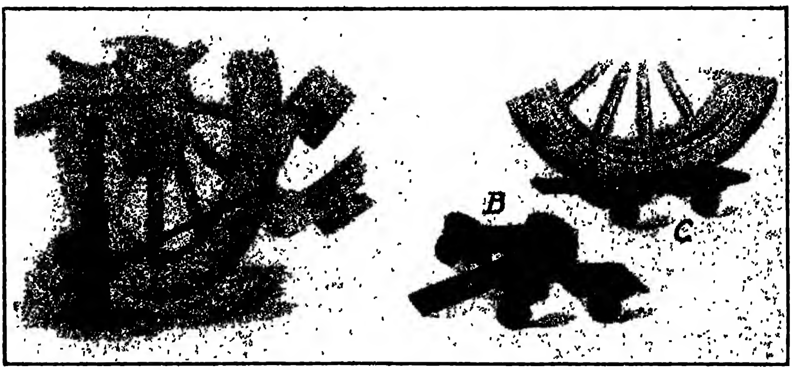


Fig. 13.—Method of Utilizing Simple Substitute for Turntable.

can run in any direction. To use this useful accessory the first step is to jack up the car as shown at A, and then run the truck under the wheels letting the wheels down when the truck is in place. The car may be run onto the trucks under its own power at one end while it is necessary to raise the other two wheels in order to use the small truck. When four of these are used, one under each wheel, it will be possible to swing the heaviest car around without much exertion.

An objection offered to the large turntable is that a pit is necessary in order to have these flush with the floor level, and most of the structures offered are costly. A very simple arrangement that will work very well without requiring alterations to the floor is

hown at Fig. 14. This rests directly on the floor and consists of a ircular iron track having a number of ribs or spokes radiating to a entral hub which serves as a pivotal point for the load carrying arriage. The carriage is made up of two channel iron beams fasened together by a spacer casting, having at its center a suitable earing to engage the pivot pin. This serves merely to locate the oad carriage and is not called upon to support any of the weight, which is carried by a series of wheels resting on the track and ecurely attached to the side flanges of the channel section beams. As the height of the beams from the floor is but two inches, it is

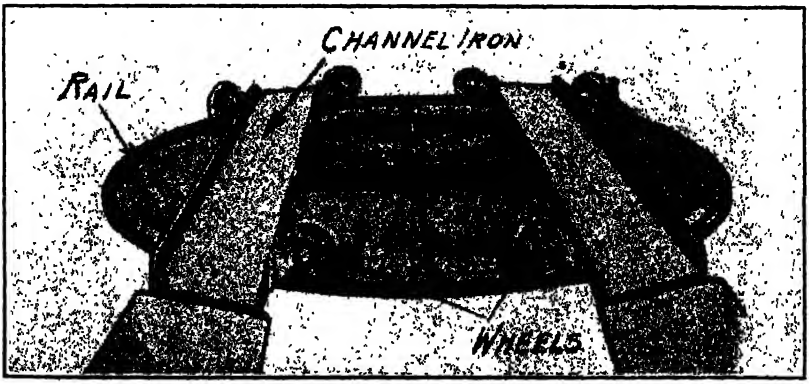


Fig. 14.—Outlining Construction of Pitless Turntable.

ossible to use a pair of wedge shape planks as an approach to the urntable. The side of the channel irons also serves a useful purpose esides offering a means of securing the supporting wheels and pacer frame, inasmuch as they offer a guide so the wheels of the ar cannot run out of their correct path. These turntables may be ecured in sizes, capable of handling any weight of car and will e found an effective substitute for the more expensive built-in urntable.

Two forms of built-in turntable are shown at Fig. 15. It will be observed that with these it is necessary to make a pit in which a ortion of the mechanism is concealed. The form shown at A is built up of angle irons and steel plates and the load is carried at

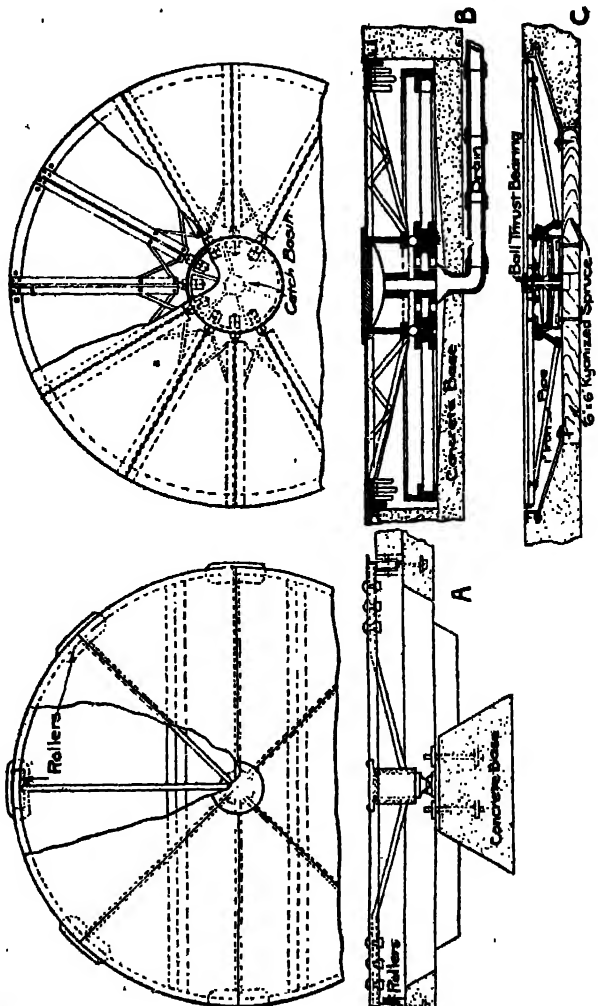


Fig. 15.—Designs of Turntable Suitable for Garage Use.

the centre by a pivot or step journal mounted on a substantial concrete base and at the outer periphery by a series of rollers carried in supporting castings securely anchored to the concrete foundation. The form shown at B, carries the weight on a large ball bearing and has an added feature of having a catch basin for water and other drippings from the car at its centre, so this material will be conducted to a drain instead of filling the pit as is the result when no precautions are taken for drawing the liquid off. The design shown in section at C, is a modification of the type illustrated at B.

One of the most useful of the accessories comprising the assembling floor equipment is the load-raising and supporting jack, various forms of which are shown at Fig. 16. The type at A, is a ratchet form having a single trip lever which can be set so that the same movement of the actuating bar will either raise or lower the lifting ram as desired. The jack at B, is similar to that at A, except that the lifting ram is provided with a double head, making it possible to use the jack on those low axles where it is difficult to get the jack directly under the member to be raised. The jack at C, is a double geared arrangement in which the nut serving to raise the lifting screw is turned by bevel gears worked by the customary lever. The tire saving jack which is shown at D, is used for keeping the wheels of cars that are to be stored for some time off the floor and thus relieve the tires of the car weight. These jacks have the advantage of being very quickly handled and are used one under each hub cap of the car to be raised. The lifting ram may be adjusted to suit different wheel heights by means of a series of ratchet teeth which enable the lifting link to secure either a long or a short hold on the ram member. In addition to the types of jacks shown, a number of other forms have been marketed which do not give the quick lifting necessary for use in making repairs, but which are much stronger and better adapted for weight carrying purposes when the car is to be supported for any length of time. The form shown at E, is composed of three substantial wooden legs, forming a tripod and jointed together at their apex by angle pieces of steel. The lifting ram or screw may be raised or lowered by imparting motion to the nut resting on top of the wooden tripod. The form at F,

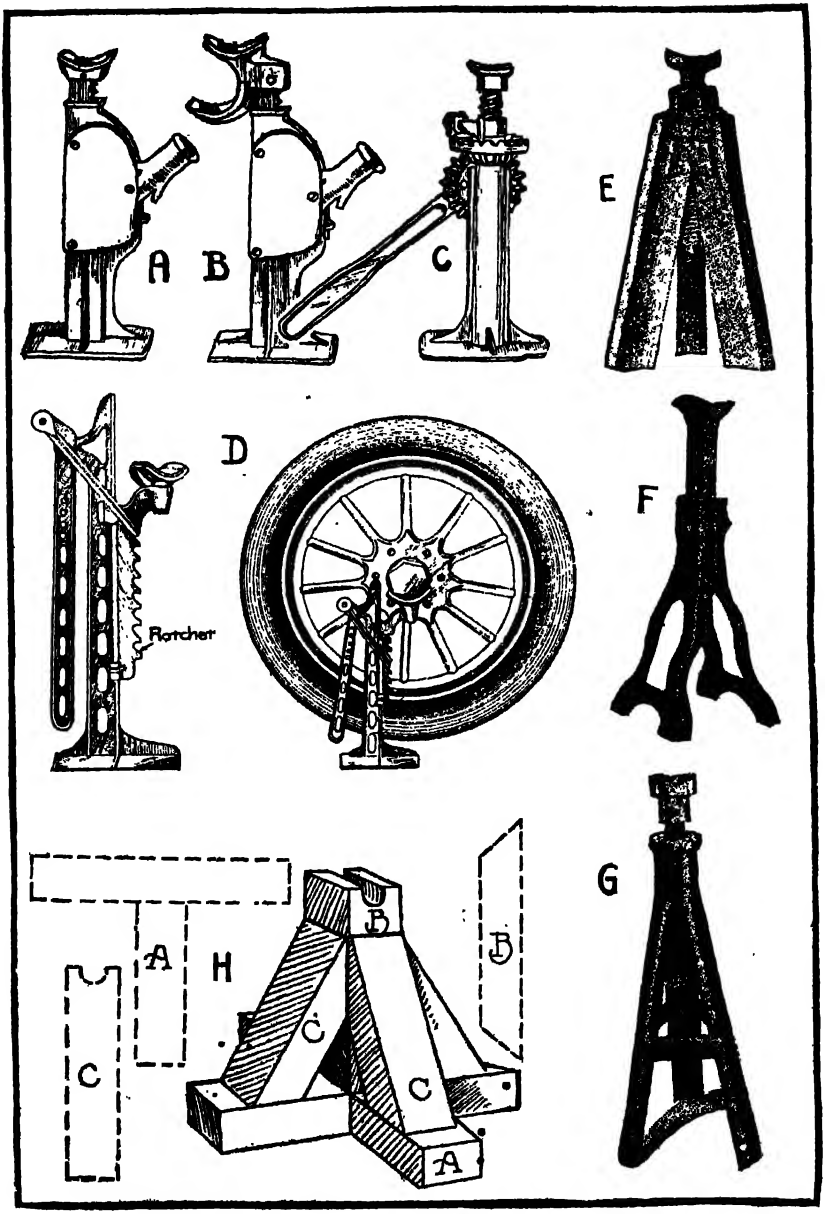


Fig. 16.—Practical Forms of Car Raising Jack

is composed of three castings, the centre one being placed under the car axle, while the two outside ones form the base of the device. The height of the load-carrying member can be adjusted to a degree by placing the clamping bolt which holds the assembly together through the desired hole in the lifting ram. The form at G, is similar in action to that at E, except that the tripod is a substantial member made by slotting a steel tube at three points and then spreading the legs apart and joining them by the brace pieces near the base. The jack or support at H, may be constructed by any repairman and is made of substantial timbers. The construction is so clearly shown that further description should be unnecessary.

Every repairman has occasions when it is necessary to take care of a car which has met with some accident to the wheels, axles or steering knuckles, so that it is impossible for the car to proceed on its own wheels. Towing such a car back to the garage is a tedious job if proper provisions are not made for supporting the injured end of the car in a secure manner and yet one that will not offer any appreciable friction. The common method of procedure with a broken axle or wheel on a horse-drawn vehicle is to use a heavy beam as a support for the injured member, one end being secured to the good axle, while the other is allowed to trail on the ground. This is not a good system to use with a heavy automobile, because the friction between the end of the beam and the ground is so great that it will be a great strain on the towing car if the load is to be moved for any distance. A simple emergency truck which is known as the Weaver Ambulance, and with which the makers claim one driver is capable of towing in a disabled car, is shown at Fig. 17, A. The truck and one method of using it is illustrated, and the marked feature is the ease with which it may be attached and removed. Besides being used to support the front end of the car, as in the illustration, the truck may be employed as a substitute for any one of the wheels. The tongue portion is adjustable to suit requirements of the work to which the device is applied.

Mention has been previously made of the utility of a portable crane in the repair shop. These are capable of handling a wide diversity of work and it is a practical and not expensive sub-

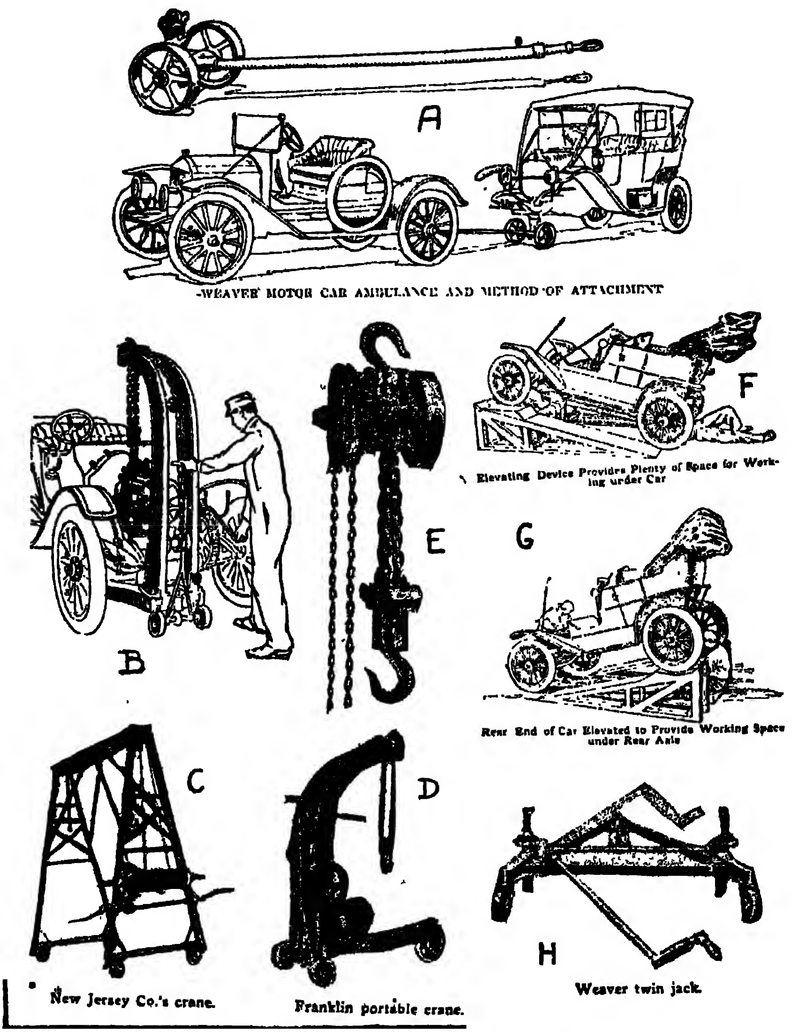


Fig. 17.—Weight Carrying and Lifting Appliances for the Repair Shop.

titute for an overhead rail system. In the repair shop, for instance, it has the special advantage of being able to get into places hat the overhead crane cannot reach. This form may be taken

to the work, whereas the work has to be taken to the usual overhead trolley. It is of strong construction, and one man can handle four thousand pounds by its aid, picking the same up with ease, transporting same, and placing it in any desired position. These cranes are made in various styles, the ordinary range of sizes adapted for repair shop work varying from one to three tons' capacity. The crane shown at D is a very substantial and strong form, and is shown in use lifting an engine out of a frame at B. Another form of portable hoist is shown at C. This is virtually a high trestle mounted on wheels and well braced. Two winding drums are used, each serving one lifting rope. Owing to the drum operation by small pinions and long hand cranks, the leverage is very great, and one man may raise any load within the capacity of the crane.

The need of some form of chain hoist in garages where the portable crane is not used is more marked at the present time than was formerly the case when automobiles and their components were lighter than they are to-day. The rapid growth of the motor truck industry also means that heavy pieces must be handled. Where it was formerly common practice to cast motor cylinders individually and in pairs, it is now general practice to use 4 and 6 cylinder block castings which are difficult to handle, especially in the larger sizes.

The chain hoist also forms an important unit of all overhead trolley systems, as a very effective travelling crane may be contrived by using a simple wheeled trolley, running on a commercial T-section beam and having a hook to which the chain falls may be attached. The Simplex chain hoist shown at Fig. 17, E, is a two-speed device permitting great leverage and slow speed for heavy loads, and greater speed, though lessened leverage, for lighter weight. As will be noticed in the accompanying illustration, an endless chain runs over a chain wheel, which in connection with a pinion and brake wheel with ratchet teeth in its outer rim forms an automatic brake to prevent the load from descending.

The pinion attached to the hand chain wheel drives a spur gear, which is keyed to a second shaft, at the end of which is another pinion. The last named member engages with an internal spur

gear, which is keyed to the opposite end of the main shaft, to which is attached the lift chain wheel. Motion is transmitted from the hand chain to the lift chain, and by pulling on the hand chain, in either direction, the load is lifted or lowered. When hoisting a load the brake wheel, with its ratchet teeth on the

Fig. 18.—Showing Practical Use of Portable Crane in Automobile Repair Work.

outer rim, rotates freely with the hand chain wheel and pinion, and without resistance, as the ratchet pawl runs freely over the teeth. When the pull on the chain wheel ceases, the pawl engages with the teeth of the ratchet on the brake wheel, preventing it from running backward, and so keeping the load suspended.

In lowering the load the hand chain is pulled in an opposite

direction, and but little effort is required to overcome the friction of the automatic brake, thus permitting the load to descend and holding the same suspended again, as soon as the workman stops pulling on the hand chain. The load can be lowered at a good rate of speed by a continuous pull upon the hand chain. By means of an ingenious arrangement of the lower block, the lift chain is locked to the chain wheel of the lower block, providing the two speeds referred to, making for economy of time in handling light loads. Closed rings attached to a swinging frame provide guides for the hand chain, enabling the operator to stand away from under a load, pulling the chain at an angle, without producing any appreciable amount of friction or wear on the chain or guide. The construction eliminates the possibility of the chain wedging between the wheels and guides.

In many shops it is inconvenient to provide pits by which the workmen may gain access to the under portions of an automobile. A very practical elevating device which provides plenty of space for working under a car is shown at Fig. 17, F and G. In the former illustration the front end is shown raised, while at G the rear end is elevated. This consists of a light, inclined runway made of planking and timbers upon which the car may be run. A pair of hollowed blocks at the upper portion in which the wheel tires fit provides a positive stop to prevent the car from rolling off the stand.

Another useful device for use on the assembling floor that saves considerable time when an entire end of a car is to be raised, as is necessary for inspecting parts of the steering system or rear axle faults, is shown at H. This is known as the Weaver twin jack, and consists of a triangular framework mounted on wheels and carrying two lifting screws actuated by bevel gears near the base of the triangular frame. A cross shaft carrying similar sized bevel gears actuates the lifting nuts on the vertical screws, and is in turn operated by a bevel gear turned by a pinion, to which motion is imparted by a hand crank. The gearing is so arranged that a large amount of leverage is provided and the heaviest car may be raised without any exertion. The hand crank is mounted in a swivelling bracket, which makes it

possible to operate the jack without stooping or to fold the handle over entirely out of the way. As the jack is carried on a wheeled frame, the car may be moved around even if the two wheels on the axle supported by the jack are removed.

A reader of "Motor Life" sends a description of a quick action lifting jack that is very well adapted for garage use, though too bulky to be included as part of an automobile equipment. This form has been widely used in connection with racing, as an entire front end of a car may be easily raised and held by the force exerted by one man at the end of the long lever when a quick tire change is necessary and where every second counts. The usual form of lifting jack operating on either the ratchet or lifting screw principle would require considerable time to raise the wheels clear off the ground, whereas the form depicted at Fig. 19, A, will do the work in 15 seconds.

This consists of a handle or lever, 8 or 10 feet long, supported and pivoted between two uprights attached to the base. Underneath the front end of the lever is a swinging post which supports the weight of the car when in a vertical position. The size of the parts and strength of the lever will vary with the weight of the car. The base, uprights and handle may be of wood. The base should be about 20 inches long and 6 or 8 inches wide, having the uprights mortised into the sides and braced with blocks on the inside corners. The uprights may be about 4 inches wide, both these and the base being of 1-inch material. The height of these uprights and length of the post will depend upon the diameter of the wheel and the amount it is to be raised. Supposing that the distance from the ground to the underside of the hub or axle is $15\frac{1}{2}$ inches and that the wheel is to be raised 3 inches, then, allowing $1\frac{1}{4}$ inches for the thickness of the base, the length of the post will be $17\frac{1}{4}$ inches minus the thickness of the lever under the wheel.

This post or support may be made either of wood or iron, and pivoted underneath the lever in any convenient manner so that it will swing freely. An iron rod with one end bent to form an eye may be obtained from any blacksmith shop for a few cents. A bearing may be formed for this rod either from wood

blocks or heavy sheet metal attached to the sides of the lever as shown. The holes in these blocks as well as the eye in the upper end of the post should be large enough to take a three-quarter inch bolt. Another three-quarter inch bolt may be used to support the lever in the uprights. There will be considerable space between the sides of the post and the blocks, and this may

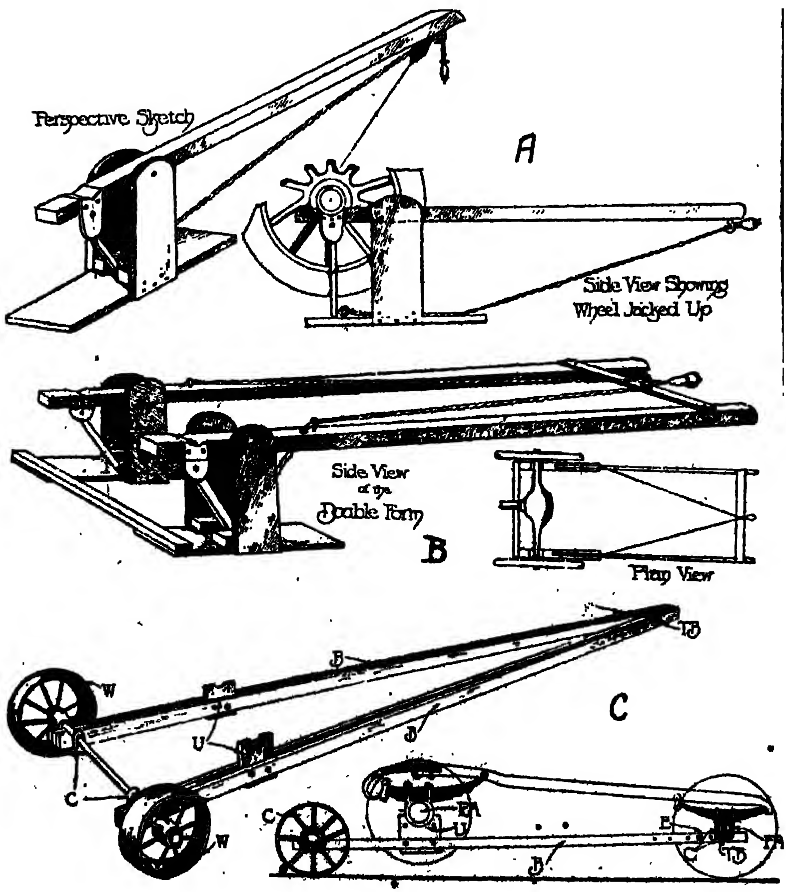


Fig. 19.—Quick Action Car Lifting Jacks and Truck for Use in Towing Disabled Cars.

be filled by using a number of three-quarter inch washers on the bolt. The same method may be used to fill the space between the lever and the two upright pieces.

On the top of the lever, directly above the support where the hub or axle rests, a shallow V-shaped groove should be cut so that the axle cannot slip off the jack when raised. The underside of each end of the base should be rounded off so that the jack can be slid over the floor of the garage without the corners catching on projections. The operation of raising the wheel is quite simple, since all that is necessary is to slip the jack under the hub or axle so that the weight will come directly in the groove above the support, when the car is raised by pressing down on the outer end of the lever. Since the supporting post swings freely it will assume a vertical position when the car is raised, so that when the weight is taken off the outer end of the lever the post takes the entire strain of the load. In order to facilitate removing the jack from the car, a small wire rope should be attached near the lower end of the post and run through a ring in the outer end of the lever. Thus when the lever is pressed down the post swings free and may be pulled back from under the wheels.

The jack is shown from two different viewpoints in illustration, but it seems that the builder of this has not taken the fullest possible advantage of his opportunities. If, as he says, jacking up is slow and tedious work, the device as shown only eliminates the work of raising the car by means of the jack, and substitutes for it the task of prying up one wheel at a time, then putting blocks or some firm and stable object of the right height under the axle, next letting the jack down and moving to another wheel. With the device as constructed, it would take four different applications to lift a car entirely clear off the floor, two at the rear axle close to each wheel, and two at the front axle, near each wheel.

It is possible to reconstruct the jack as outlined so this work may be reduced to two applications, one for the rear axle and one for the front. This is done by constructing the jack about as outlined, but in duplicate, fastening the two together at the front end and also at the rear. In addition, it will be necessary to make the handle much longer and stouter, for whereas the former

jack lifted but 700 to 1,100 pounds or higher, according to the size of the car, this one will be required to lift just twice as much every time, namely 1,400 to 2,200 pounds, according to the size and weight of the car.

For this reason, also, it would be well to increase the proportions all over. Devices of this sort have been built and used in many racing contests, in which the smallest fraction of a second was valuable. The device in those cases was built of metal throughout, light weight being of no object. When the signal came for a tire stop on the next round, this was wheeled out into a convenient position, and when the car stopped it was slid under the axle, a couple of men jerked it down, raising the entire axle so wheels stood clear off the ground, and in less time than it takes to tell it, another pair of men were replacing the wheels and tires, or tires alone, as the case might be. These were so made with definite proportions that when fully pressed down the jack would stay down of itself and did not require a man to stand and hold it.

A home-made cradle for bringing in cars having an injured axle or wheel is outlined at Fig. 19, C. It can be constructed by any mechanic of average ability from odds and ends, and as it does not take up much room it can be stored conveniently when not in use, though many uses will be found for it in the garage, even when not employed for the purpose for which it was primarily intended. This consists mostly of a built-up pair of beams forming the two long sides of a very acute triangle, the third side of which is formed by a pair of small metal wheels and an axle, such as might be found on any old farm wagon or other heavy truck. The axle is securely attached above the side beams, which are fastened together at the front. About 18 inches to 2 feet forward of this axle a pair of vertical supports are formed with a notch in the upper surface large enough to take an ordinary rear axle. In the sketch, the side bars are marked *B, B,* the uprights for the car axle *U,* the wheels, *W, W,* the clips holding the axle to the sidebars *C,* the forward ends *E,* and the tie bolt holding them together and making a point of attachment *TB.* The second sketch shows the method of use; the cradle is pushed under the

chassis, so that the uprights catch the rear axle *RA*, then the front end *E* and the through bolt *TB* are fastened to the front axle *FA* by means of the chain *C*. This being the case, the rear wheels of the car do not rest on the ground, but the small iron wheels, *C*, of the cradle do, and the car is pulled home on these and the regular front wheels.

The same outfit can be used for an underslung frame by laying a board across in place of the uprights, and resting the rear axle of the car on this. In doing this, the uprights must be removed, so the board should be made with a pair of extensions and this bolted in place, using the same bolts as with the uprights. A device of this kind has recently been placed upon the market by a western firm, this being finished up very neatly all over, while the sketch simply gives the idea for a more or less rough home-made cradle.

Machinery Equipment for Small Shops.—The amount of machinery used in repair shop equipment will depend entirely upon the size of the shop and the character of the work it caters to. The requirements of the average small shop will be met very well by the use of a 16-inch screw-cutting lathe, a sensitive drill press, an emery grinder or twin wheel stand, and a forge outfit. If all classes of work are to be attempted, a small shaper will be found very useful, as much of the work that can be done on a milling machine can also be accomplished on the shaper, which is a less costly machine tool. In all repair shops, irrespective of size, the lathe is really the most important tool, and one good sized machine of this kind should be included in the equipment of any repair shop worthy of the name, no matter how small. Practically all classes of machine work may be done on a lathe, as very efficient attachments may be obtained on the open market that will enable a machinist to do milling, gear cutting, and grinding on this universal machine tool. Drilling may be done without changing the lathe in any way. About the largest part to be handled in any repair shop would be an engine flywheel, as far as diameter is concerned, and the longest piece would probably be a six-cylinder crankshaft or live axle. It is not necessary to install a lathe capable of swinging 24 inches in order to have a tool available

for work that would be unusual, as very effective results may be obtained by using a gap bed lathe which can be purchased at but slight extra cost over that of the regular tools. The advantages of this type of lathe will be considered in proper sequence. A lathe that will swing 16 or 18 inches will be sufficiently large for most shops, though it can be supplemented by a smaller size adapted for lighter work if the funds permit. In buying lathes, especially for a small shop where the machine tool equipment is necessarily limited, it is well to remember that small work can be handled in a large lathe much easier than large work can be turned in a smaller one, and where it is imperative that but one tool be purchased, it will be the best economy to install a substantial machine. If a drill press is included, one that will swing 24 inches has been found large enough to handle nearly all parts of automobiles. The sensitive drill press is used for drilling small holes, and should have a capacity so that it will handle drills up to a half inch diameter, at least.

Machine Tool Equipment for Complete Repair Shop.—An unusually complete machine tool outfit is shown in the shop plans at Figs. 5 and 6. With an equipment of this nature all kinds of repair work may be accomplished economically and, in fact, the outfits shown are sufficiently complete so competent mechanics will be able to build an automobile without outside assistance. As the lathe is the king of machine tools, the major portion of the equipment consists of these useful machines. Seven lathes are provided, two being ten inch swing, three fourteen inch swing, one eighteen inch swing and one capable of handling work up to twenty-four inches in diameter. A universal milling machine upon which a wide variety of work may be done is a useful adjunct to the lathe. A milling machine can finish flat or irregular surfaces which a lathe cannot do unless fitted with a milling attachment. It will make Woodruff keyways or straight splines, it can cut gears, cams and do a variety of other work that cannot be done on the simple lathe.

A small shaper having about sixteen inches stroke is also useful, because it will do much of the work done on a milling machine and require simpler tools. While a milling machine has

a greater range of work and will do it more economically than the shaper, the latter can be used to advantage in many cases where the cost of milling cutters would be much more than that of making the shaper tool and doing the work besides. Both milling machine and shaper should be provided, if possible. Three drilling machines are provided, one a sensitive drill for light work, the intermediate size, a back-geared drill press, and for extremely large work, such as drilling frames, boring cylinders, axle housings, etc., a radial drill is very useful, as it will handle any part of a motor car irrespective of size. A power hack saw, two emery grinders, one used for roughing purposes and the other for tool grinding, and an arbor press, complete the equipment of this machine shop.

Power for the Shop.—Just as electric current is superior for lighting, it also has many advantages as a source of power. The electric motor is an ideal power generator, because it is clean, efficient, economical, easily started and stopped, compact and capable of standing considerable overload. It makes possible individual motor equipment of machine tools in large shops and can be used very effectively for driving the line shafting of the smallest establishment, because it can be suspended out of the way on a platform hung from the ceiling or in the smaller sizes placed on a shelf attached to the wall or some convenient post. Where electric current is not available and where it is not profitable to install a generating plant, the gasoline engine is an economical method of supplying power. The marked advantage of electric current is that it may be employed not only for lighting, but for operating various portable drills, polishing machinery, air compressors, etc., and it also has a great advantage of generating current that can be used for charging storage batteries, which are now included in the equipment of all up-to-date automobiles, as a source of current for the electric self-starter and lighting system. Where electric current is not available from a municipal central station, a garage or repair shop of any size will find it more economical to install a generating plant and make its own electricity for lighting and power than to use a steam or gasoline engine which can only fur-

nish power and then depend upon kerosene and acetylene lamps for lighting, which naturally increase the fire risk.

Small Generating Sets.—A typical generating set consisting of a four cylinder gasoline engine driving a direct current dynamo is shown at Fig. 20. The equipment is furnished in various sizes, and an outfit can be purchased that will furnish current econ-

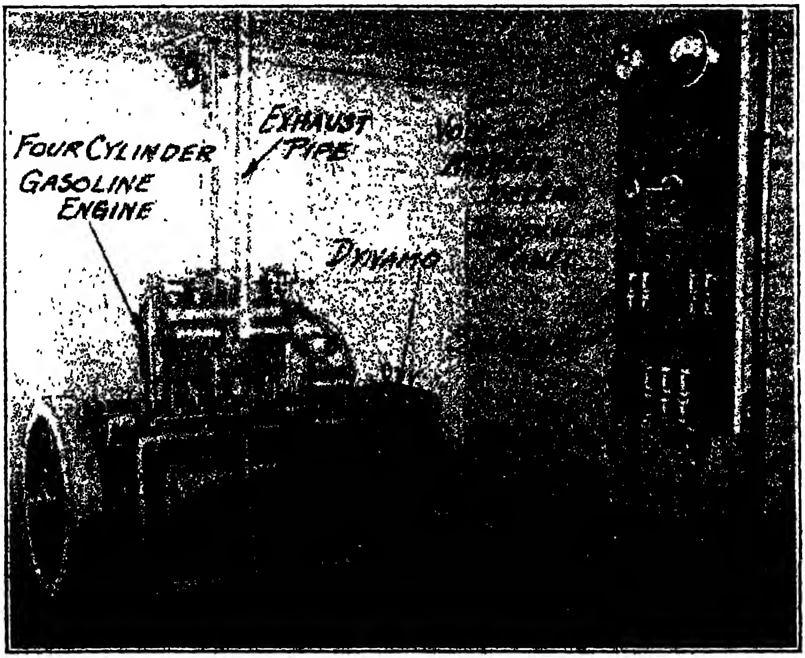


Fig. 20.—Isolated Power Plant for Generating Electric Current.

omically for even the smallest shop. The outfits include switchboards and all necessary governing and control appliances, and once the engine is started it requires no further attention, as it will perform the various functions incidental to controlling its speed and power automatically. Instead of using the line shaft, as would be necessary with a gas engine belted direct, it is possible to install individual motor drive on the various machine tools, an example of which is shown at Fig. 21. When one considers that

the average line shaft consumes from 20 to 30 per cent. of the power delivered to it in journal friction, if any number of hangers are used, or if the shaft is not absolutely aligned, it will be apparent that the use of individual motor drive will reduce this power loss appreciably. When only two or three machines are to be driven, it is, of course, more profitable to drive these from a short length of shafting than it would be to provide a separate motor

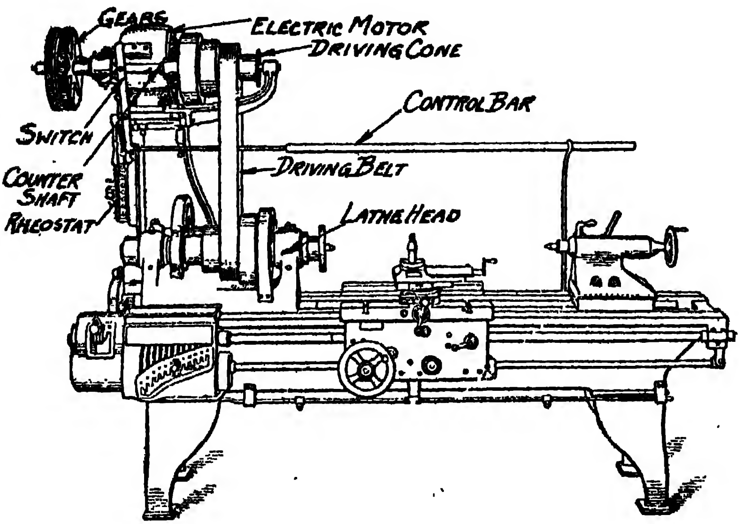


Fig. 21.—Form of Lathe Adapted for Direct Drive from Electric Motor.

for each machine tool, as one motor may be made to serve them all where the power requirements are not great.

The writer does not mean to imply that the internal combustion motor in its various stationary forms is not adapted for power delivery in small units, because many repair shops, some having a very complete equipment, obtain their power directly from an oil engine which is the most economical of the various power-generating units. When a generating set is used it is necessary to use an engine of greater power than would be needed if belted directly to the shaft line, but as in most installations

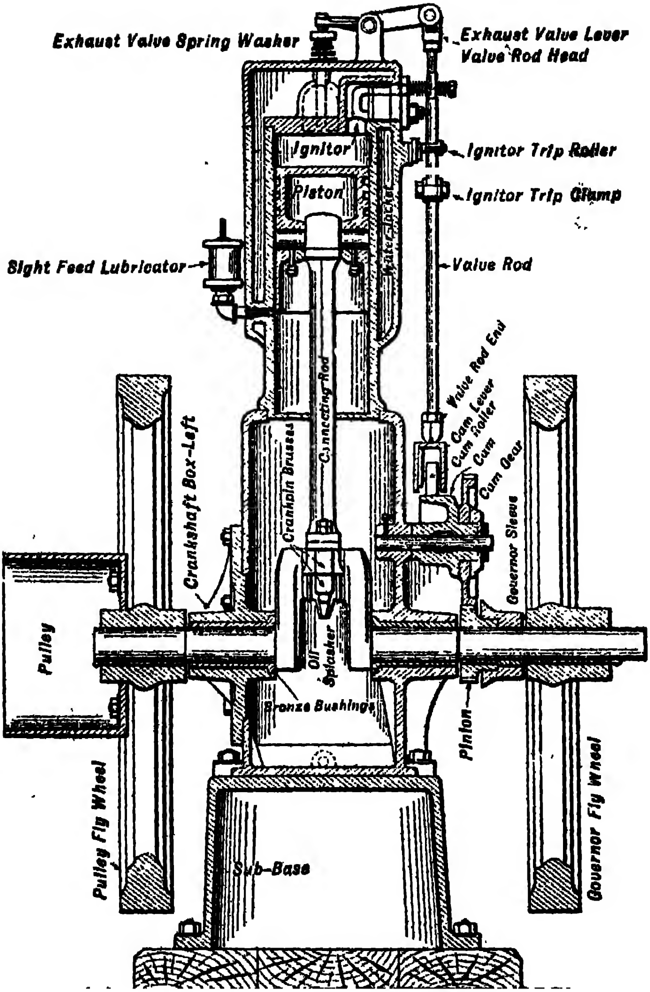


Fig. 22.—Sectional View of One Cylinder Vertical Gas or Gasoline Engine Suitable for Automobile Repair Shop Power Plant.

the electrical current is to be used for lighting as well as power it is, of course, necessary to provide an actual surplus over the power needed to run the shop in order to furnish the current for illumination.

As practically all automobile mechanics are familiar with the explosive motor, owing to its almost universal use as a prime

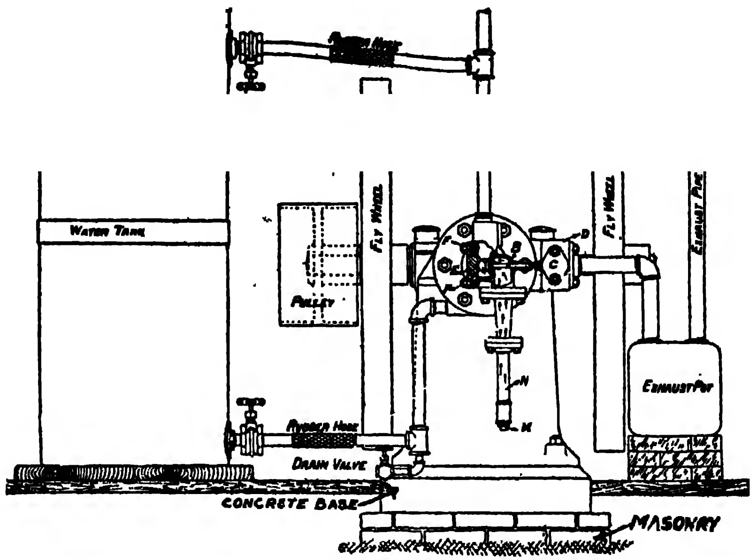


Fig. 23.—Outlining Method of Installation of Stationary Gas or Gasoline Engine for Shop Power.

mover in automobiles, it is reasonable to expect that many isolated repair shop owners will avail themselves of the opportunity to use a source of power with which their workmen are thoroughly familiar. A one-cylinder vertical engine adapted for stationary power is shown in section at Fig. 22. Two large flywheels are used to insure steady running, and the power generated may be delivered to the shop line shaft by direct belt connection between the engine pulley and a corresponding member on the shaft. The

method of installing a horizontal engine adapted for stationary power and the provisions made for cooling the cylinder and disposal of the exhaust gases are so clearly shown in Fig. 23 that it is unnecessary to describe the installation further. For the very small shop using but few machine tools, it is not necessary to use the type of cooling system required by the larger powered engines, as the two or three horse-power necessary to operate a small lathe, drill press and emery grinder can be delivered economically from the simple hopper cooled engine, such as shown at Fig. 24.

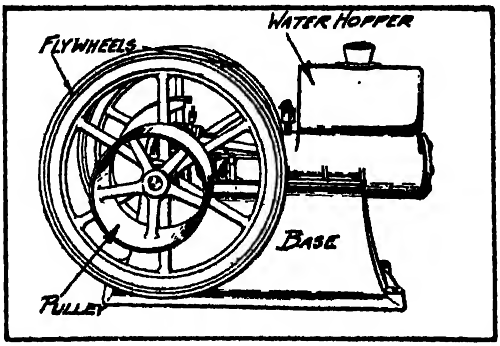


Fig. 24.—Gas Engine Suited for Small Repair Shop.

Where a gas or gasoline engine is used for power, it is necessary to provide a substantial foundation composed of masonry and concrete as shown at Fig. 23, or of heavy timbers as shown at Fig. 22, in order to prevent excessive vibration of the floor. If possible, the engine bed should not rest on the floor, but the foundation should be carried down to solid earth. The smaller hopper cooled engine of two or three horse-power may be bolted directly to the shop floor, as these will not vibrate enough to be objectionable. A marked advantage of an isolated generating set such as shown at Fig. 20 is that it may be housed in a structure separate from the repair shop proper, reducing the first risk, whereas, where an engine is belted directly to the line shaft, it is usually in the same building as the machinery it drives.

One of the important advantages accruing through the use of a gas or gasoline engine is in the economy of this form of power. If an engine is used capable of running on fuel oil instead of gasoline, there will be a marked saving, and the absolute limit in the low cost of power production will have been reached, the only forms of power showing to better advantage being those de-

rived from natural sources, such as wind and water, neither of which can be applied universally. The table of power cost presented herewith shows the relative expense of various forms of power among which are included three forms of steam engines, the gas engine using manufactured or natural gas, the internal combustion motor using gasoline, the electric motor and the oil engine. Where the power requirements are not severe, the gas or gasoline engine in the smaller sizes will not prove so expensive to operate as to call for the use of an oil engine which is not as easily started or kept in operation as the forms burning gas derived from the various gas-producing methods or by the vaporization of volatile hydrocarbons, such as gasoline.

TABLE OF POWER COSTS

Type of Power	Kind of Fuel	Price of Fuel	Fuel Consumed per Horse-Power per Hour	Cost per Horse-Power per Hour	Cost per Horse-Power per Year of 300 Days, 10 Hours per Day	Cost of Generating Electricity, per Kilowatt Hour (Generator Efficiency 89½ per cent.)	Saving of Oil Engine per Horse-Power per Year (Fuel 2¼ cents per gallon)
Steam Simple Engine	Bituminous Coal	$3.00 per ton	8 pounds	$0.01200	$36.00	$0.01800	$27.60
Steam Compound Non-Condensing	Bituminous Coal	$3.00 per ton	5 pounds	$0.00750	$22.50	$0.01125	$14.10
Steam Compound Condensing	Bituminous Coal	$3.00 per ton	3 pounds	$0.00450	$13.50	$0.00675	$ 5.10
Gas Engine	Illuminating Gas	$0.75 per 1,000 cubic feet	18 cu. t.	$0.01350	$40.50	$0.02025	$32.10
Gas Engine	Natural Gas	$0.30 per 1,000 cubic feet	12 cu. ft.	$0.00360	$10.80	$0.00540	$ 2.40
Gasoline Engine	Gasoline	$0.12 per gallon	1 pint	$0.01500	$45.00	$0.02250	$36.60
Electricity (Motor Efficiency 85 per cent.)	....	$0.02 per Kilowatt hour	$\frac{878}{1,000}$ kw.	$0.01760	$52.50	....	$44.10
Oil Engine	Fuel Oil	$0.02¼ per gallon	1 pint	$0.00280	$ 8.40	$0.00420	......

Power Required for Machine Tools.—The amount of power to be provided in a repair shop depends entirely upon the character and number of machines to be driven. If a line of shafting is to be used to turn the machinery, and especially if there are individual countershafts for each machine, as is needed for most machine shop tools, it will be necessary to double the power requirements of the tools used, as given in the accompanying tabulation, to take care of loss of power through belt slip, journal friction, lack of machine alignment and other causes. The figures given are taken from the best mechanical authority and are an average of some widely different estimates for the same class of machine.

Energy Consumption of Common Machine Tools

Machine	H. P.
Sensitive Drill	.32
Back Gear Drill Press (20″)	.42
Back Gear Drill Press (30″)	.45
Radial Drill (medium size)	1.12
14″ Lathe	.26
16″ Lathe	.38
24″ Lathe	.44
30″ Lathe	.65
Speed Lathe	.15
Milling Machine (small)	.19-.29
Milling Machine (large)	.83
Shaper (14″)	.35
Shaper (24″)	.52-.70
Planer (small)	.00
Planer (medium)	.50
Tool Grinder (one wheel)	.97
Tool Grinder (two wheel)	1.15
Heavy Roughing Grinder (two wheel)	1.90
Polishing Stand (High Speed)	1.00
Power Hacksaw (12″ to 14″)	.06

Installation of Machine Tools.—The placing of the machinery will depend entirely upon the ideas of the master mechanic and the best method of installing line shafting will, of course, depend upon the character of the building and the materials of which the

wall or ceiling to which it is attached is constructed. If the floor space permits, the machinery should be arranged so that all may be driven from a single main line of shafting. It is well to remember that a reduction of the length of the shaft and the number of hangers for its support decreases journal friction and consumes less of the shop power. If the machines are on the ground level, as is the case with most small shops, the floor may be made of heavy planks, attached to substantial beams laid over a foundation of cinders or well grouted crushed stone. A floor of cement should always be planked over because the wood flooring is much easier on the feet of the workmen. It seems almost unnecessary to mention that a perfectly level floor should be sought for. It is imperative that the floor be substantial enough so it cannot vibrate and have sufficient strength so it will not deflect under the weight of the machine tools. There is some danger from this source, if the machine room is placed on an upper floor of a converted building that has not been especially constructed for automobile repair work. All machinists and millwrights agree that the foundation for the bed of a machine should have no deflection, if the life of the machines and the accuracy of the work performed upon them is to be given consideration. The problem is considerably simplified when one considers that in automobile repairing, machine tools of great weight are not used, so there should be no difficulty due to either floor vibration or deflection in any ordinarily well constructed building.

The floor plans presented at Figs. 3, 4, 5 and 6 inclusive show logical arrangements of machine tools that can be followed to advantage. The lathes, milling machines and shapers should be installed where there will be plenty of light upon them, and it is well to group all lathes together, if possible. Drilling and boring machines must be installed with ample floor space around them so the large work can be handled to advantage. Ample room should be allowed around each individual machine, and there should be sufficient space between the benches and tools to allow the workmen at the bench to pass between the operator at the machine and the bench with room to spare. An ideal method of installing an electric motor, if this is used as a source of

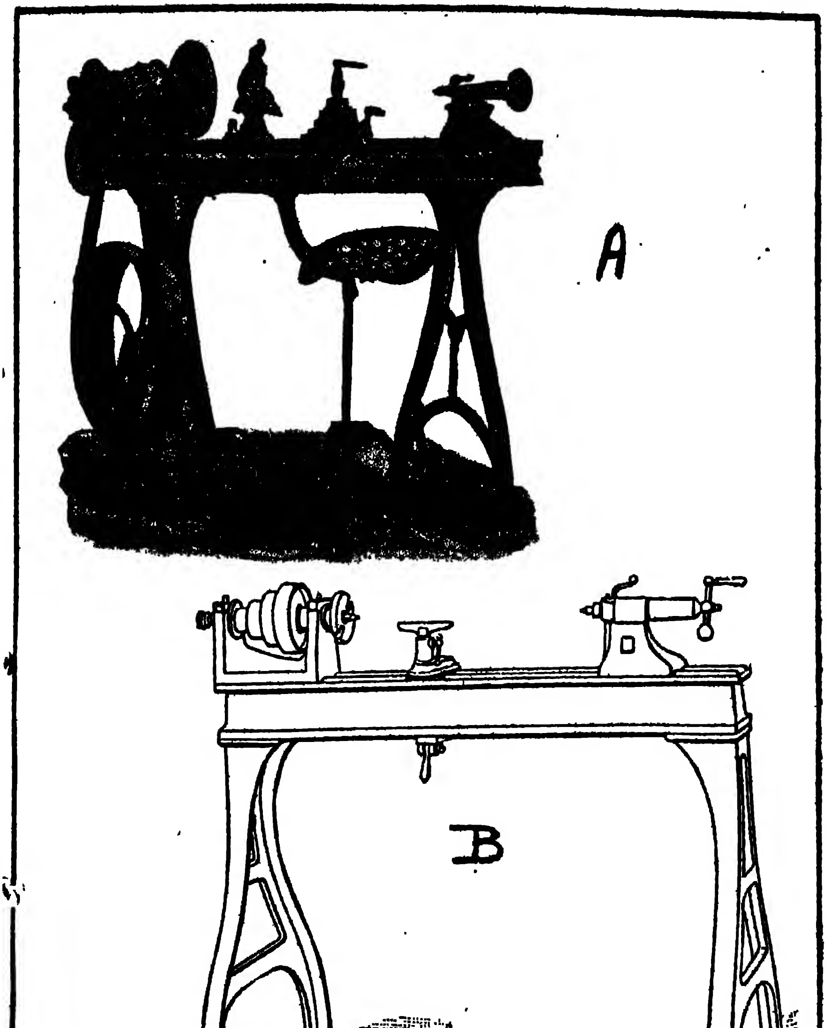


Fig. 25.—Simple Forms of Lathes.

power, as would be the case in any city or town where central station current was available, is to support it on a stout platform suspended from the ceiling at any convenient point and to make a direct belt connection with the main driving pulley of the line shafting. The proportions between the motor armature pulley and that on the line shaft should be such that the speed of the shafting will not exceed 300 R. P. M. The switches, starting rheostats and fuse blocks should be placed on one panel at a convenient height on the wall. As an electric motor needs but little attention, in some shops it is hung directly from the ceiling, i.e., the base is securely attached to the beams by lag screws. If precaution is taken to change the location of the lubricating oil wells under the main journals, a motor can be operated just as well upside down as in any other position. Where central station current is procurable and but few machines are used, the individual motor equipment does not have the advantages in a small establishment that are presented in its favor when used in the large manufacturing enterprises. While an individual motor for each machine eliminates a large amount of overhead shafting, belting, etc., and conduces to a lighter and cleaner shop, it is doubtful if the advantage of rendering each tool or machine independent of the others as regards power would compensate for the cost of such an equipment. It is doubtful if individual motor drive would be an economy in the repair shop if one considers that most companies supplying current make a fixed service charge, this being figured so closely that it is almost as cheap to keep a low power motor going all day as to keep shutting it off and on or using a varying number of smaller motors having in the aggregate somewhat less power. Besides, in a repair shop of any size, it is not likely that there will be any lull in the work. and power would be required from morning to night.

The Lathe, Types and Accessory Equipment.—Two very simple forms of lathes which are better adapted for the private garage repair shop than for general work are shown at Fig. 25. That at A is a foot power machine that is capable of doing very fine work, and that is well adapted for experimental and light repair purposes. It will swing nine inches and has a space of 25 inches

between centers. The tail stock can be set over for taper turning, and a swivel tool carriage permits a wide range of work. It is provided with a lead screw and is suitable for thread cutting. The lathe at B is a small speed lathe that is shown with a tool rest adapted for hand-turning tools. This can be replaced by the usual form of cross slide rest, making it suitable for metal turning work. A small lathe of this nature is included in many repair shops for wood turning and is often fitted with a drill chuck and used in place of a sensitive drill for light drilling. A machine of this kind is inexpensive and very useful. The light screw-cutting lathe shown at A is also furnished with a countershaft, making it suitable for power drive, though a surprising quantity of accurate work may be accomplished without unduly fatiguing the operator, if the foot power form is utilized.

All lathes, with the possible exception of the speed lathe, in order to be thoroughly practical for repair shops, should have screw-cutting attachments, elevating compound rests, hollow spindles and a good outfit of auxiliary attachments. Several sizes of chucks and face plates, and a steady rest and back rest for long work, should also be provided. A lathe that will cut from four to forty threads per inch has sufficient range for all ordinary shop work. A number of different designs of lathes of latest pattern suitable for repair shop use are shown at Fig. 26. That at A is the conventional form of engine lathe that has been so universally applied in the machine shops of the world. It is back geared and provided with a complete set of gears for screw cutting. The difference between this lathe and that shown at B is in the change speed gear box provided, by which any desired speed of travel of the carriage may be obtained by merely shifting a lever. In the form shown at A it is necessary to remove the driving and stud gears, and in some cases the lead screw gears, and replace them with others for varying classes of work. In the form at B any desired gear ratio within the range of the tool may be obtained by the simple movement of a gear-shifting lever.

The lathe at C is a gap bed type, one of which should be included in the equipment of practically all repair shops, and if

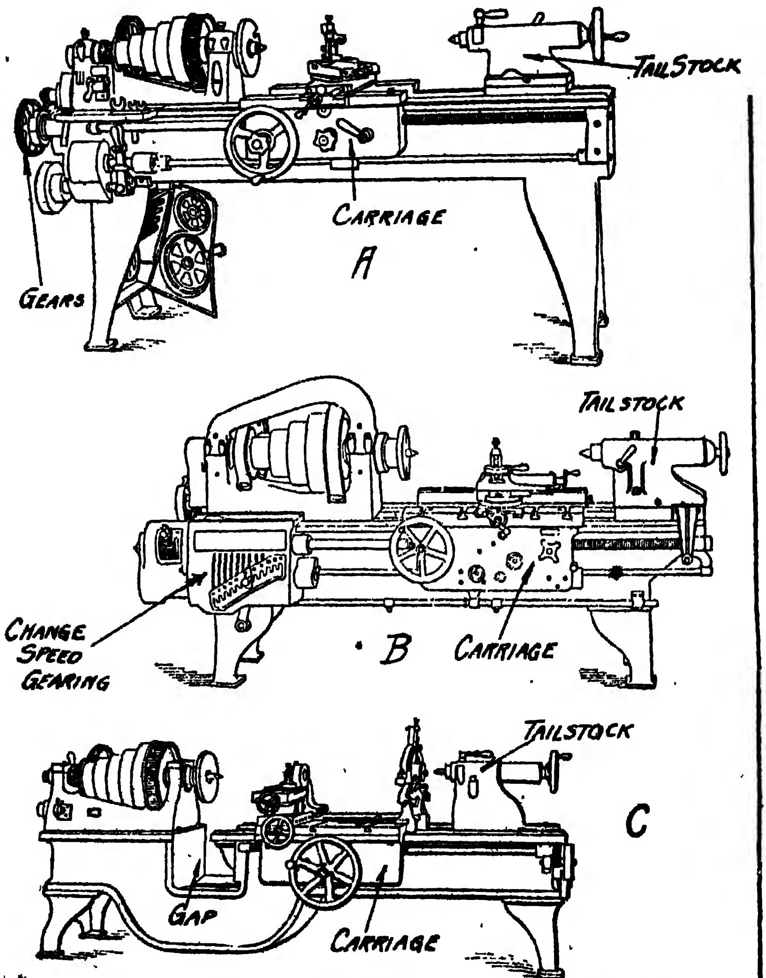


Fig. 26.—Outlining Practical Designs of Lathes for Automobile Repair Shop Use.

only one lathe can be purchased this should preferably be of this type. The gap in the lathe bed makes it possible to swing much larger work than would be possible in either of the forms shown at A or B, and a well designed gap bed will not be appreciably

weaker than the solid bed form. All ordinary work may be handled on a lathe of this form, and in addition, the out-of-the-ordinary jobs, such as machining a flywheel, facing a large clutch cone or plate, etc., can be accomplished when desired.

A complete outfit suitable for most of the requirements of garages and general repair shops, which sells for approximately

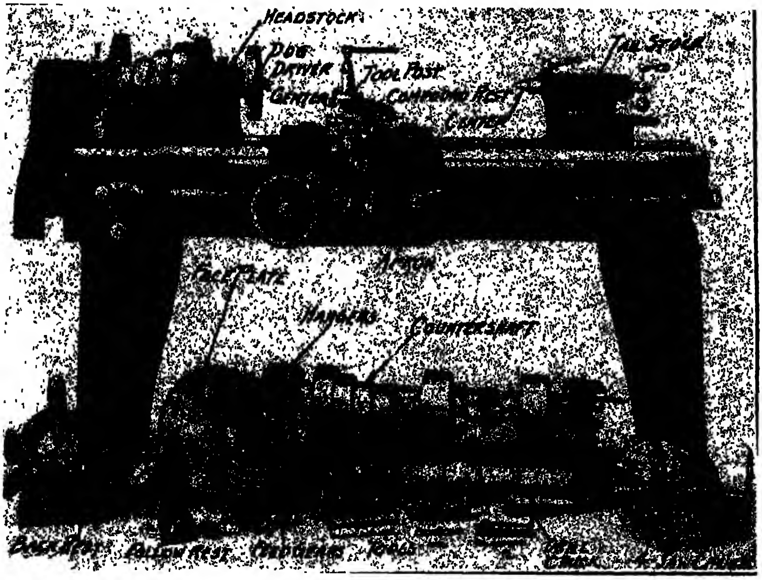


Fig. 27.—Typical Screw Cutting Engine Lathe with Complete Equipment Adapted for Automobile Repair Work.

\$200, is shown at Fig. 27. This includes a 13-inch swing x 5½-foot bed, back-geared, screw-cutting engine lathe. It is provided with automatic longitudinal and cross feeds. The cone pulley has four steps for a two inch belt. The ratio on the back gearing is 7 to 1. The tail stock is cut away to permit the compound rest to be swung around to 90 degrees, and is fitted with a sleeve, bored to conform to Morse taper No. 4, and has a self-discharging center. The tail stock may be set over for taper turning. The cross feed screw has a graduated collar so the feed may be regulated to one-thousandth

of an inch. Change speed gears are furnished to cut threads from 5 to 36, including 11½ pipe thread and one extra compound gear to cover all special threads from 3 to 72. The special garage equipment consists of the parts outlined in illustrations. These are large and small face plates, follow rests, steady rest, compound rest, centers, wrenches, full set of change speed gears, double friction countershaft, four jaw independent chuck, drill

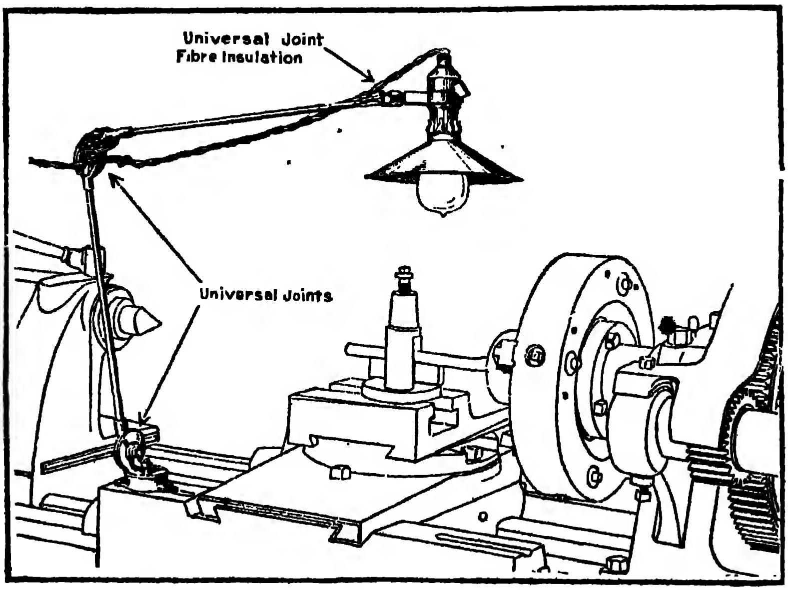


Fig. 28.—Useful Lamp Supporting Bracket for Use on Lathe.

chuck, set of lathe dogs, and a set of turning and boring tools. An equipment of this nature is not only practical, but if the complete outfit is purchased the garage man is sure of obtaining a practical machine tool for all ordinary repair work. The outfit shown would be the same regardless of the size of lathe purchased, except that the auxiliaries, such as face plates, chucks, and tools, would be all properly proportioned for the machines they were to be used with. In purchasing a number of lathes it is not necessary to buy a full equipment for each lathe. For instance, two chucks

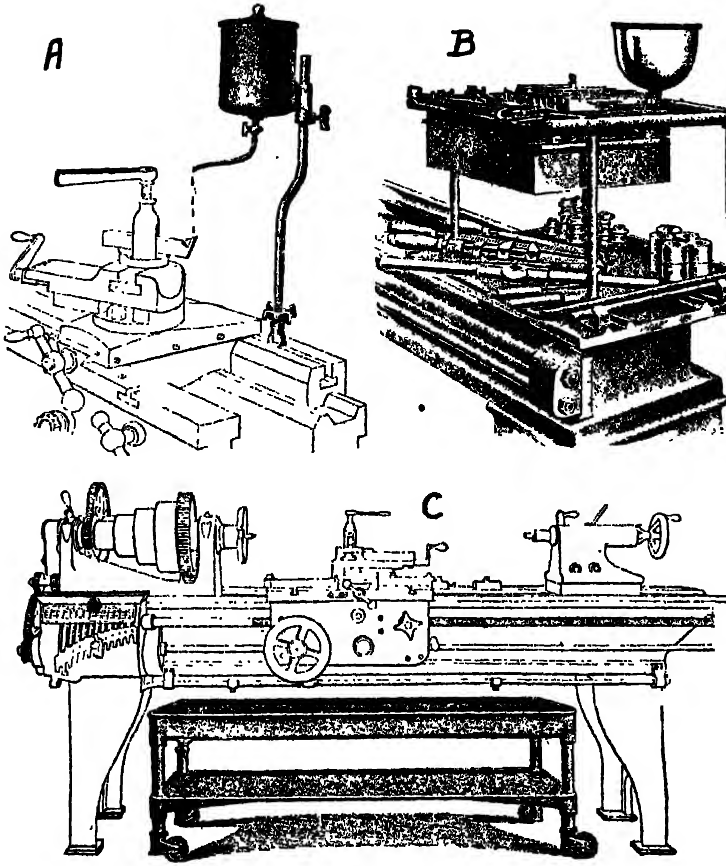


Fig. 29.—Useful Appliances to Facilitate Lathe Work.

and two face plates would be enough for four lathes if these were of the same size. The follow rest and steady rest, which are not used continually and forming the part of one lathe outfit, would, of course, be suitable for any others of the same pattern. The various types of lathe tools, chucks, etc., will be considered more at length in the next chapter, which deals with the small tool equipment of the shop.

A lathe is not complete without a number of additional con

veniences, such as shown at Figs. 28 and 29. The importance of proper illumination of the work is apparent, and this may be assured by using a universally jointed incandescent lamp support such as shown at Fig. 28. The universal joints make it possible to set the lamp at any desired angle and at any point that is most convenient for the operator within a wide range. When cutting resisting materials, such as the alloy steels used so widely in automobile construction, as well as when taking roughing cuts, the lubricant container shown at Fig. 29, A, is of value, as it not only is capable of ready attachment to the lathe carriage, but will direct a constant stream of lubricants or cutting compound on the point of the tool in order to prevent it from becoming overheated. As the container is supported by the carriage, it must move in proper relation with the cutting tool. The rack shown at B is an important adjunct, inasmuch as it provides a place for holding the machinist's tools where they will be accessible and yet out of the way. The base of the rack is designed to fit the lathe shears, and will keep various wrenches, files, etc., out of contact with the lathe ways. A drawer is provided, which may be locked, in which the machinist can keep his finer tools, such as the micrometers, calipers, etc. Another adjunct to the lathe is the tray mounted on a wheeled stand shown at C, designed to be placed under the lathe bed to catch chips and borings of metal and keep these from the floor. Its construction is very simple, and as it is made entirely of metal, it is durable and fire-proof. The various articles of equipment outlined are marketed by the New Britain Machine Company.

Shapers, Planers, and Drilling Machinery.—Both the shaper and planer remove metal from flat surfaces, whereas the lathe is essentially a tool for machining cylindrical surfaces. In the shaper, which is shown at Fig. 30, A, the work is mounted in a fixed work-holding vise, while the cutting tool is carried in a tool post mounted at one end of the reciprocating shaper head. The work may be moved laterally by hand or power feed, while the tool may be raised or lowered to get the depth of cut by the lever C. The tool post is mounted on an index so that it may be set at any desired angle. As previously stated, much of the work that can

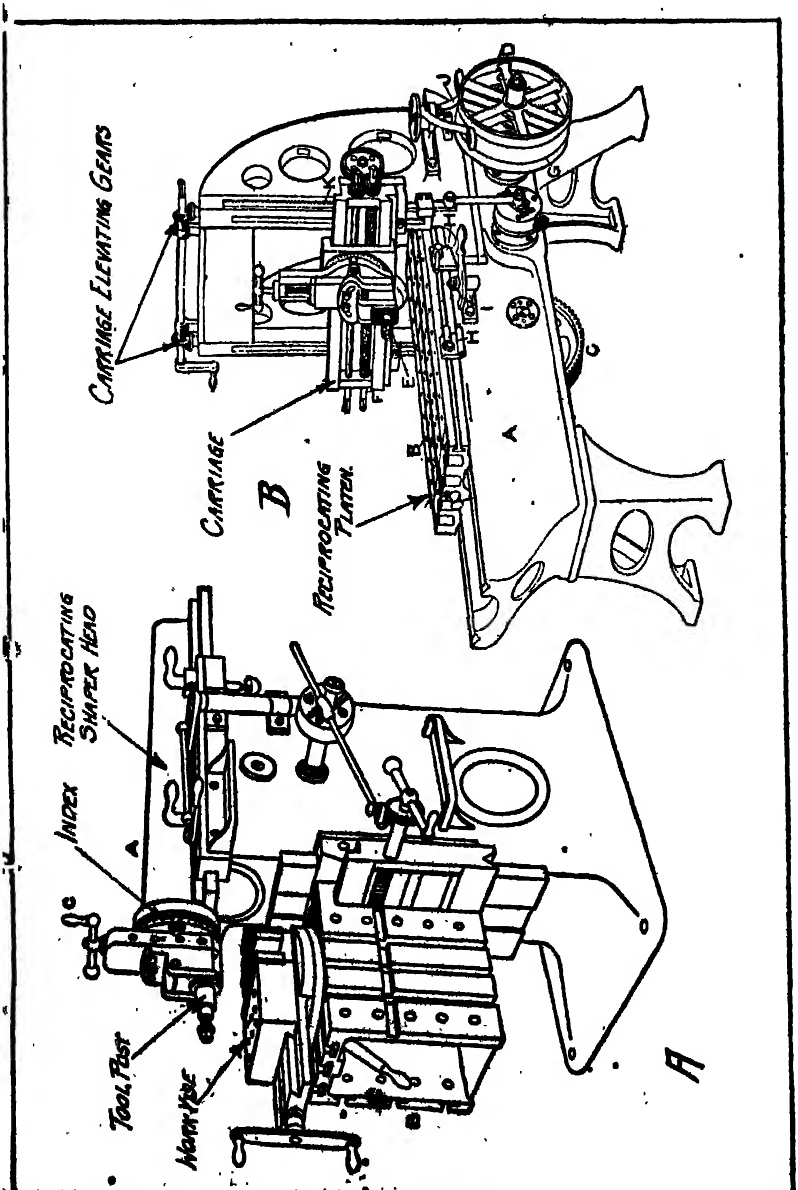


Fig. 30.—The Shaper and Planer, Two Machine Tools of Utility in Motor Car Restoration.

be done on milling machines can also be performed on the shaper with less expensive tools.

The planer, an example of which is shown at Fig. 30, B, is better adapted for handling large work than the shaper. In a planer the tool is fixed relative to the work, except as relates to vertical or lateral feeds. The tool is clamped in the tool post E, which is provided with an index fixture similar to that of the shaper and a hand feed lever for setting the depth of cut. The tool post carriage may be moved up or down on the supporting standards by means of a hand crank which operates the bevel-raising gears. The work to be machined is secured to the planer bed or platen B, which slides upon the ways machined in the bed A. As will be evident, the work is brought against a fixed cutting tool, whereas in the shaper the work is fixed and the cutting tool reciprocates over the work surface. A planer is useful in machining large objects such as motor crank cases, gear boxes and machining the flat surfaces on cylinder castings.

The drilling machinery provided should include a back-geared drill press having a table capacity to swing 24 inches. A typical machine of this nature of good design is shown at Fig. 31. The tool should be back geared, meaning that the spindle speed may be slowed down for handling large drills or doing heavy work. It should have both hand and power feed and a table adjustable for both height and position. In the machine shown the table may be swung entirely clear or off to one side and large work supported directly on the base which is provided with slots capable of taking T-bolts. The spindle which holds the drills may be raised by a hand lever for quick feed, by a hand wheel acting through worm gearing for slow feed and by level gears for power feed. The spindle drive shaft is provided with a keyway and passes through the main drive bushing which is driven by bevel gears at the top of the column. A drill press may also be used for boring and will handle large work that cannot be conveniently supported in a lathe.

A large variety of milling work can also be done if a milling machine attachment such as shown at Fig. 32, A, is provided. This has a circular base about 12 inches in diameter and a table 16½ inches long x 6½ inches wide. A longitudinal feed of one

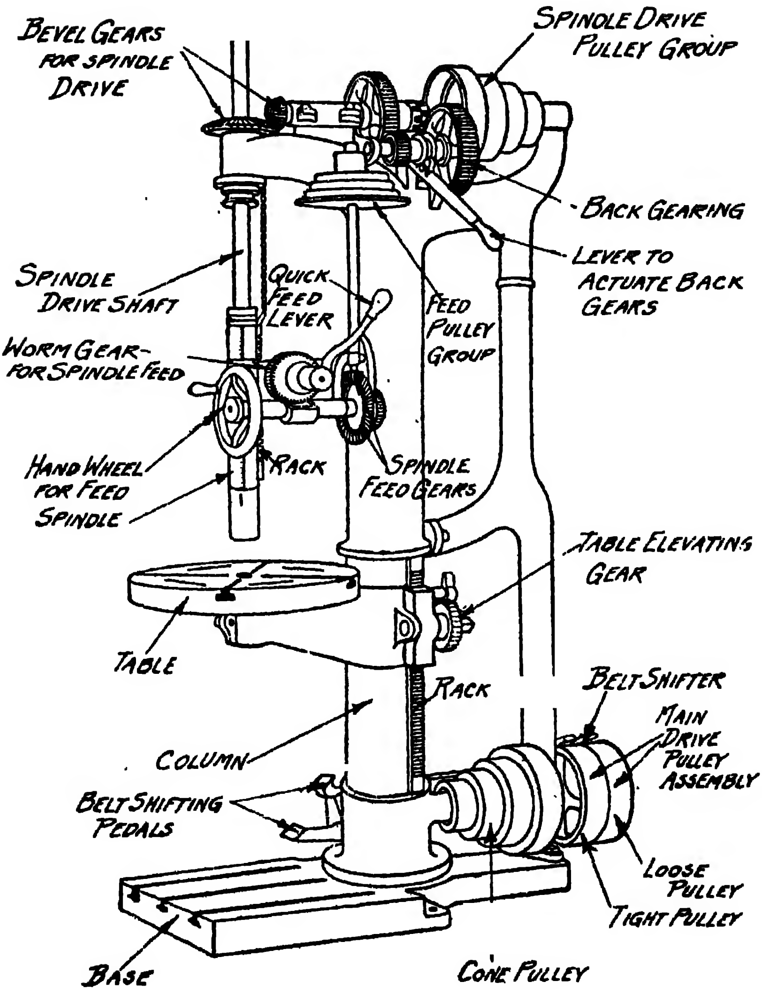


Fig. 31.—Medium Size Back Geared Upright Drilling Machine.

foot and a cross feed of 7 inches is provided by the fixture itself, which can, of course, be increased somewhat by swinging the drill table. The table of the attachment is provided with slots for three half-inch T-bolts for clamping work, and the vise jaws pro-

vided have an opening of ten inches. The table is provided with an index support so the work may be set at any desired angle.

If possible it is well to provide a smaller drilling machine having hand feed only, which is known as the sensitive drill press. This should have three or four speeds and be capable of taking drills up

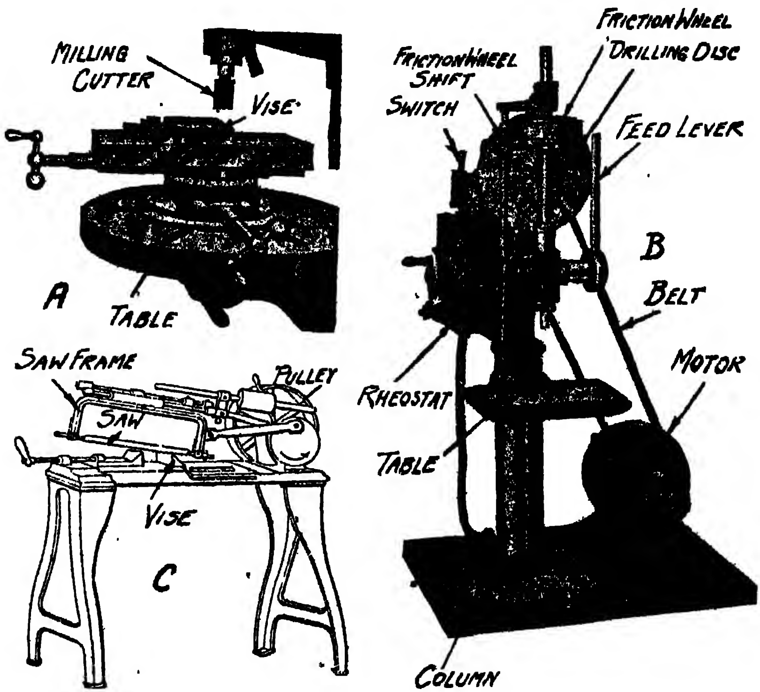


Fig. 32.—Practical Machine Tools for Small Machine Shop.

to at least three-eighths of an inch in diameter. The table should be adjustable up or down and sideways, the arm should swing to the right or left and should be of the type that permits one to put either a V-block or cup to support bar stock in its place. A light form of sensitive drill that is suitable for use on the work bench and which is electrically operated by a small motor is shown at

Fig. 32, B. A variety of speeds is obtained owing to the friction drive. The starting rheostat and switch are mounted conveniently on a base permitting secure attachment to the bench.

Among the smaller appliances that are comparatively inexpensive and yet very useful may be mentioned the power hacksaw, which is not only simple but consumes very little power and is automatic in action after once being started. It occupies but little floor space and is very useful in cutting pieces from bar stock, such as steel, iron, or brass more than an inch in diameter. A typical power hacksaw is shown at Fig. 32, C. This consists of a frame, reciprocated by a crank, which imparts its motion to the saw frame through the medium of a connecting rod. The crank is turned by a pulley which is usually belted direct to a very small pulley on the line shaft and which turns at a speed considerably lower than that member. The feed is automatic and may be varied by altering the position of the weight regulating the amount of pressure with which the saw bears against the work. The piece to be cut is securely held in a vise attached to the bed of the machine which is supported on cast iron legs in order to raise it to a convenient height from the floor. A simple trip is provided, so that when the piece is sawed through, the drive will be interrupted and the saw frame will remain stationary.

An arbor press of large capacity is almost a necessity, and in even the smallest shops some kind of a press is essential for making force or press fits, removing parts forced on, straightening bent axles or tubular housings, and for removing arbors from parts machined on the lathes or millers. A press capable of exerting 10 to 15 tons pressure will be sufficient to cope with any work brought into the ordinary shop. One or two smaller arbor presses can be used to advantage and should be mounted directly at the ends of the large lathe beds, these serving to straighten small parts, such as valve stems, etc., and to do light work in making force fits, and in inserting and removing arbors from all work in which these are necessary.

A number of different designs of arbor presses are shown at Fig. 33. That at A, has a distance between screws of 20 inches and a distance between the head and table of 36 inches. Its capacity

is one hundred thousand pounds and it weighs 870 pounds. It is a very convenient press for use in the automobile repair shop and its construction makes it specially well adapted for pressing shafts into and from pulleys, flywheels, gearhubs, etc., and also for straightening automobile shafts. The engraving shows the con-

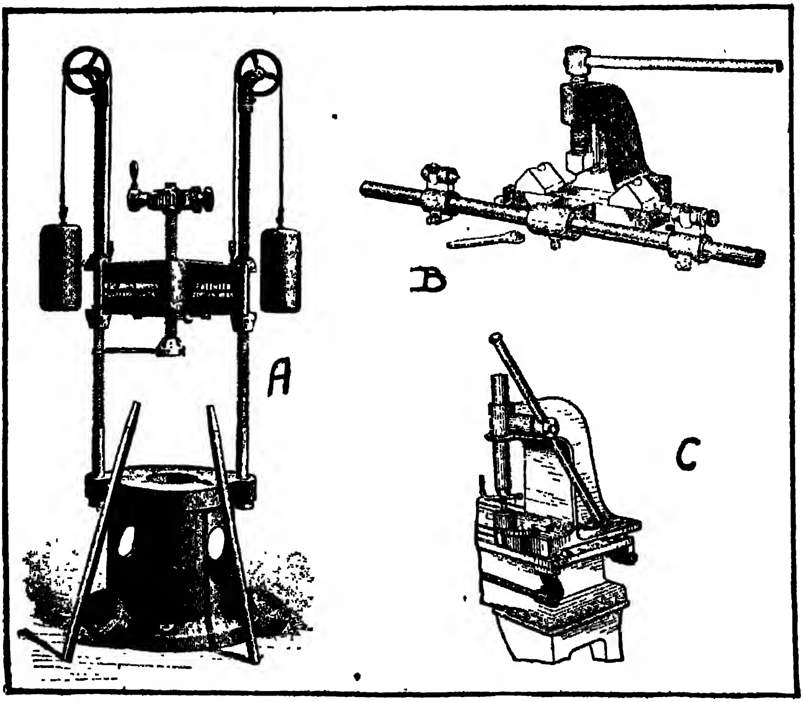


Fig. 33.—Showing Construction of Arbor Presses and Shaft Straightening Machines.

struction and principle of operation of the machine very distinctly. Two large guide screws rise from the table upon which the cross head is adjustably supported, as it has two semi-screw nuts and toggle mechanism by which the cross head is held fast or released for vertical adjustment. The cross head is balanced by weights, as shown, and a steadying bar connects the press cup with the press screw. A spur-toothed ratchet wheel is fixed on one end of the

press screw, this being embraced by a forked lever head fulcrumed to oscillate on the press screw. A double acting spring pawl engages the teeth of the ratchet, and a hand crank is attached to the press screw in order that it may be raised or lowered quickly, if desired. After the object has been placed in the press, the cross head in which the central screw is mounted can be instantly dropped to the work, and with a few turns of the screw the required pressure may be applied. An important saving in time is thus effected, compared with the method where a number of blocks must be placed on the bed plate to raise the object sufficiently to be acted on by the press screw. Tapering squared sockets are provided in each end of the pawl carrier to permit the introduction of the long bars, shown leaning against the press base, which will provide a very great leverage on the screw. The small arbor press shown at C, is of the Greenerd type and is intended to be placed on the lathe

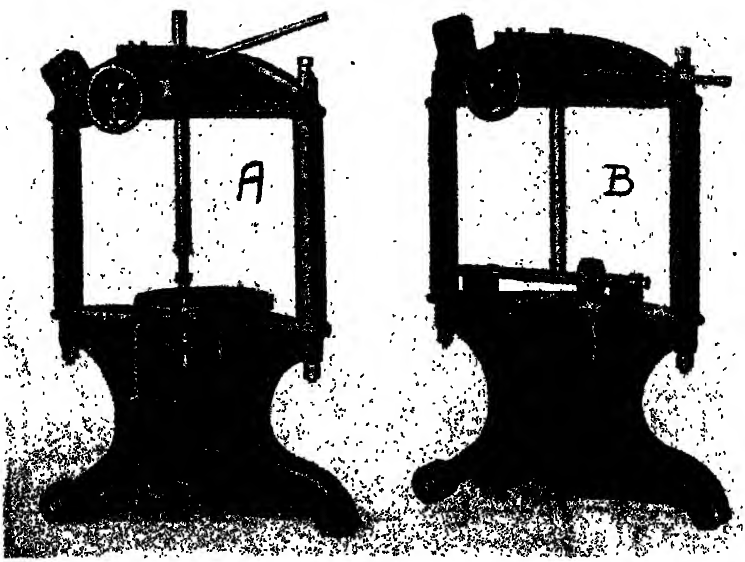


Fig. 34.—Arbor Press Design of Special Value in Automobile Repair Shop.

shears where it will be handy to the operator. Such a press is very useful for small work.

For straightening shafts a special form of press is provided which is superior for that work as it is designed for it. A typical shaft straightener is shown at Fig. 33, B. As will be noticed, it is very similar in construction to an arbor press, except that the base is provided with a slot in which V-blocks are placed to support the shaft. Another V-block is attached to the end of the screw and

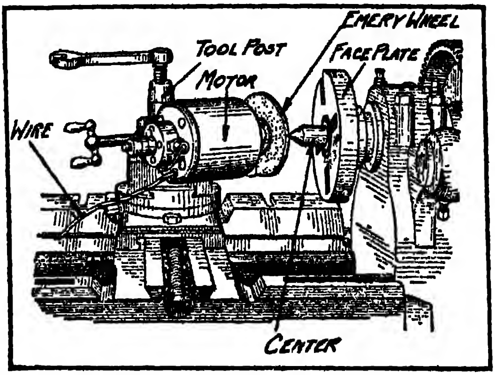


Fig. 35.—Electrically Operated Grinding Attachment for Lathe Tool Post.

bears upon the shaft. In order to ascertain if the shaft is properly straightened, a pair of centers are mounted in front of the press on a long bar attached to its base. As a shaft must be placed on centers a number of times in straightening in order to observe the progress of the work, the combination shown is evidently superior for the purpose. With the usual form of arbor press the shaft must be taken to a lathe and swung between the centers after each pressing operation. The process of shaft straightening is a comparatively simple one, as it is revolved on centers and the high spot indicated by holding a piece of chalk against the shaft surface. The high spot is then placed directly under the press screw and the pressure brought to bear against the shaft will tend to straighten it, owing to its two point support.

Another very good form of press for repair shop use is shown at

Fig. 34. At A, the method of removing gears from a shaft is shown, while at B, the press is depicted straightening a shaft. The press is easily handled, as a small hand wheel is provided on the front of the machine to run the ram quickly up or down. This press has a 36 inch space between uprights, a 12 inch opening under the plate, 26 inch over the plate and 48 inch over the lower plate or table. Being mounted on wheels the press can be easily moved to any portion of the shop to straighten an axle or over a trap hole through which a crank shaft may be placed to remove a flywheel. The auxiliary plate at the bottom of the chamber under the revolving plate has a revolving centre and is very convenient when needed. The centre of this plate is provided with a self-centering surface or a spherical or ball joint which will insure steady pressure on the centre line of the press even if the work is tilted slightly when it is initially placed. With this press one man can exert a pressure of ten tons and two men sixteen tons. With the leverage form, the workman is able to "feel" what he is doing, therefore the danger of applying excessive pressure is avoided.

Special Tool Attachments of Value.—Many special devices can be used to facilitate machine work which should be included in the equipment. In automobile repair work many irregular pieces are handled, and it would seem to the writer that a set of universal angle plates, which could be used with equal facility on the bed of the drill press or shaper or on the face plate of the lathe, would be an excellent investment. Then there are the index heads, which can be mounted on almost any machine tool, and which enable one to cut gear teeth, mill slots, or drill holes at regular intervals around the periphery of a circular piece, without time spent in laying out. The vises for holding work on the drill press or shaper should be a pattern that they can use on the face plate of the lathe, and two or three different sizes can be employed to advantage. Special boring bars, cutters, and grinding wheels should be provided, as needed. A small portable electric motor as shown in Fig. 35 mounted on the lathe tool rest can be used in grinding, both internal and external. For the sharpening of drills, cutting tools, reamers, etc., small universal bench grinders as at A, Fig. 36, driven directly by small electric motor

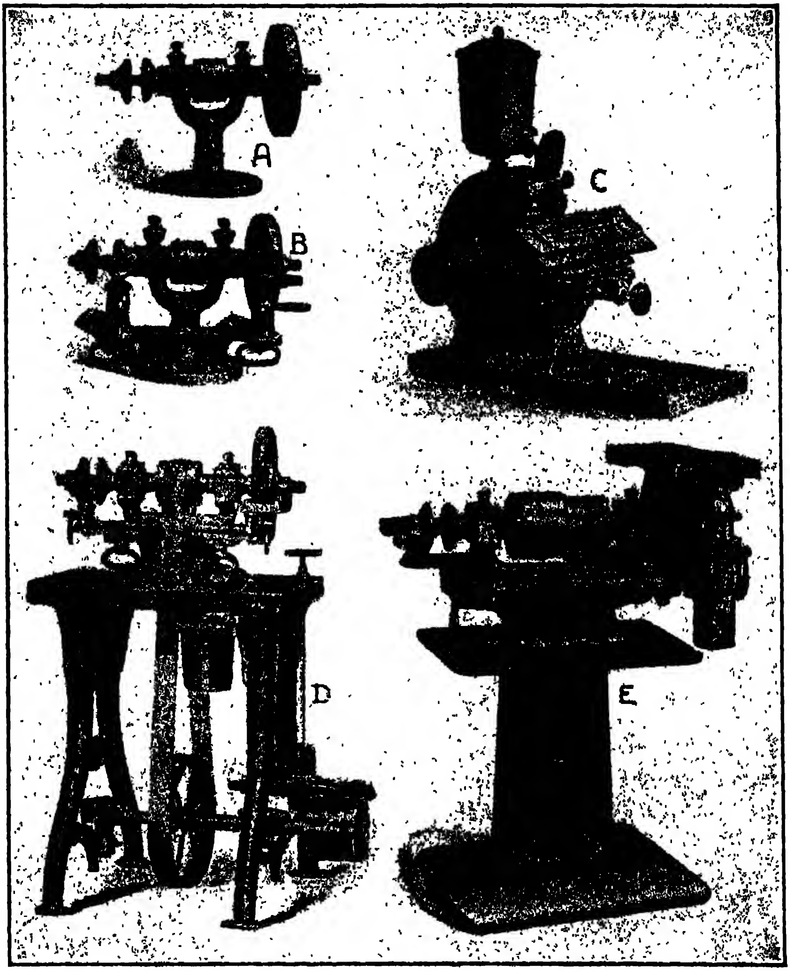


Fig. 36.—Practical Forms of Grinding Machinery.

or by belt from the line shafting, ena be profitably installed. The equipment of drills, taps, reamers, etc., will depend entirely upon the capital one wishes to invest in special epuipment, but endeavor should be made to have an assortment that will include most of the standard sizes employed in making automobile parts. These are fully considered in the following chapter.

Another form of bench grinder, provided with straight and angular rests and capable of driving two wheels, is shown at B. This is a slightly heavier form than shown at A, but is not sufficiently heavy to require the use of a special support. The grinder shown at C, is also intended to be mounted directly on the work bench and in contrast to the other forms shown, which are dry grinders, it is provided with a housing and a small water tank for all forms of wet grinding. A very useful appliance for use with a bench grinder is shown in this illustration. This is an adjustable work rest which can be set at any angle, making it especially valuable for tool grinding. The machine illustrated at D is a small two-wheeled grinder mounted on a substantial base which incorporates a countershaft beneath the table. The grinders shown at A, B and C, make it necessary to install either a countershaft with tight and loose pulleys or a clutch pulley over them to drive. The grinder shown at D, with integral countershaft can be belted directly to the main drive shaft. A grinding machine for heavy work is shown at E. This is the same in general construction as the lighter forms, except that it is much more substantial. Attention is directed to the surfacing attachment mounted over the grinding wheel. This may be raised or lowered as desired, and as the table is accurately planed and surfaced it is very valuable for grinding work absolutely flat.

In many small shops it is not possible to furnish a very complete assortment of machine tools, and while tools designed for a specific purpose are always best if they can be purchased, it is sometimes possible to do very satisfactory work on simple machines adapted for a variety of work. A small bench machine that can be used either as a lathe, drill press or milling machine is shown at Fig. 37. This may be driven by a small electric motor or can be provided with a two-speed cone pulley, as shown. At A the machine is set up for use as a drill press, at B, the change of the attachment permits it to be employed for milling. Vertical feed is provided so the milling cutter may be raised up or down, and both cross and lateral feeds of the work are obtained by hand lever. When used as a lathe it is possible to drive the lead screw through gearing so that an automatic lateral feed is obtained, this making possible thread cutting operations. The flat table shown at A, can

be supplemented by an index table for use in milling. When used as a sensitive drill the feed is by hand lever attached to the drill spindle. This tool, which is known as the "bench machinist" is furnished complete with a countershaft milling vise, face plate, dividing head and tool post. When used as a drill press, the spindle may be adjusted to any desired angle and the work brought to the tool if necessary. As a drill its capacity is up to a half inch. The spindle fits a number two standard, Morse taper shank. When

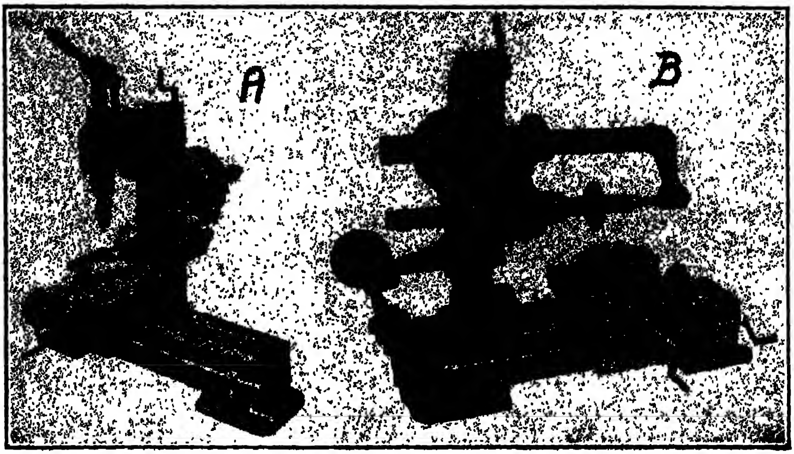


Fig. 37.—Combination Tool that Can be Used as a Lathe, Sensitive Drill or Milling Machine, Useful for the Small Repair Shop.

used as a milling machine the open side design permits the operator to do work on long pieces such as cutting keyways, straight, taper or Woodruff; squaring ends of long axle, splining and other work of this nature. The diameter of the arbor is seven-eighths of an inch and the extension arm permits the use of an arbor twelve inches long. This machine will cut small spur gears and bevel gears. It will consume but one-fourth of a horsepower whether used as a lathe, milling machine, or drill. While its capacity is limited it can handle such a variety of work that it will be found a valuable item of equipment in even a machine shop of some pretensions.

The repairman who does not use power may find a number of small machines turned by either hand or foot that will do very good work. A foot power lathe suitable for light repair work has been previously described. At Fig. 38, A, a hand-operated twist drill and tool grinder is shown, while at B, a small hand shaper which can be set up to form part of an ordinary vise is shown. The tool is carried by a reciprocating shaper-head worked by a handle, and the tool post may be raised or lowered vertically or set to any desired angle just as the larger shaper tool is. Screws are provided for both vertical and lateral feeds and a large variety of work may be done. Such a hand shaper may be used for cutting keyways, squaring shafts, repairing broken gears that have been fixed by the autogenous process where solid metal has replaced a number of broken teeth, and for many other repairs that will suggest themselves to a practical mechanic.

Miscellaneous Shop Equipment.—A number of useful articles of repair shop furniture are illustrated at Fig. 39. A and B are end and plan views respectively of a substantial stand for working on automobile engines. The end pieces are cast iron leg members having a semi-circular piece at the top. A boss is provided to support a through shaft upon which the motor carrying frame swings. When in the position shown at A, the motor is hung upside down, which provides ready access to the engine base. The motor carrying frame can be swung completely over until it is on the other side of the stand, under which conditions the cylinders and parts at the top of the motor may be easily reached. As indicated by the dotted line, the motor carrying frame may be set at any intermediate point and firmly locked in place by bolting to the semi-circular pieces at the top of the end castings. As will be apparent from the view at B, the motor frame may be designed so that the supporting members may be moved in order to hold motors of various sizes. With this form of stand it is necessary to bolt it securely to the floor owing to the overhang of the motor.

An ingenious portable work-bench which has received application in a number of European repair shops is shown at C. This is not radically different from the ordinary work-bench except that it

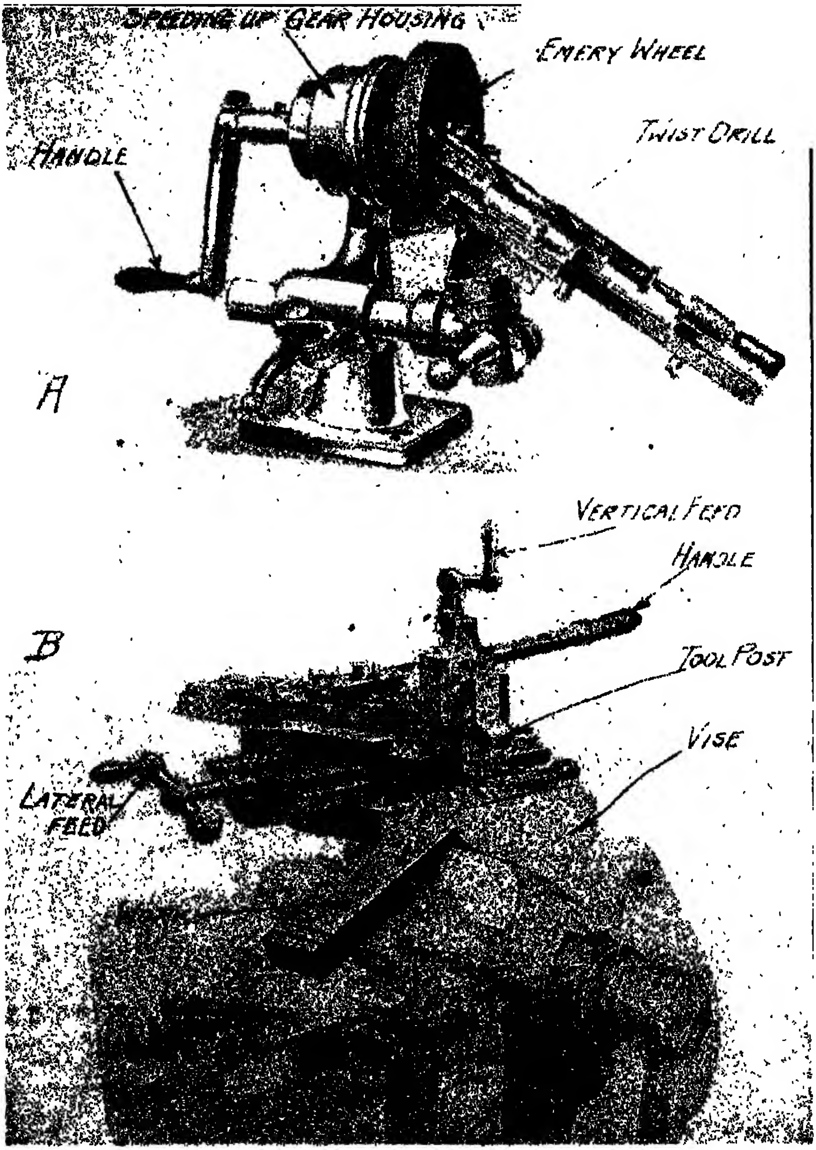


Fig. 38.—Hand Operated Tools of Value in the Small Shop.

has wheels under the legs at one end and a pair of barrow handles at the other end for moving it about. A vise is mounted at one corner of the bench, a box-like shelf underneath permits carrying parts that are to be worked on and drawers at the end of the table provide a convenient carrying-place for tools. The bench is of strong construction and its steadiness is increased by having rollers under one set of wheels only and mounting the vise and tool drawer so their weight is on the legs that have no wheels. A ledge may be placed around three sides of the bench to prevent tools from sliding off when it is moved.

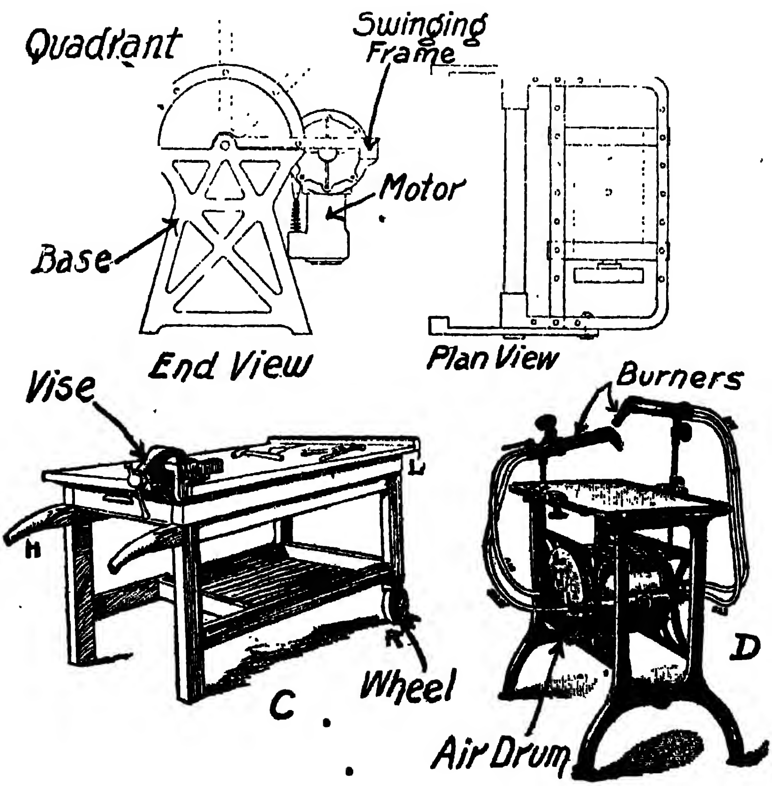


Fig. 39.—Repair Shop Furniture of Commendable Design.

Where city gas is available as fuel, the brazing stand at D is a practical article of repairshop furniture. This consists of a large cast iron table carrying an air receiver between the legs and fixtures to support the brazing torches at any desired position above the table top. The top of the table is protected by fire brick, which members are also used to form a furnace to concentrate the heat upon the

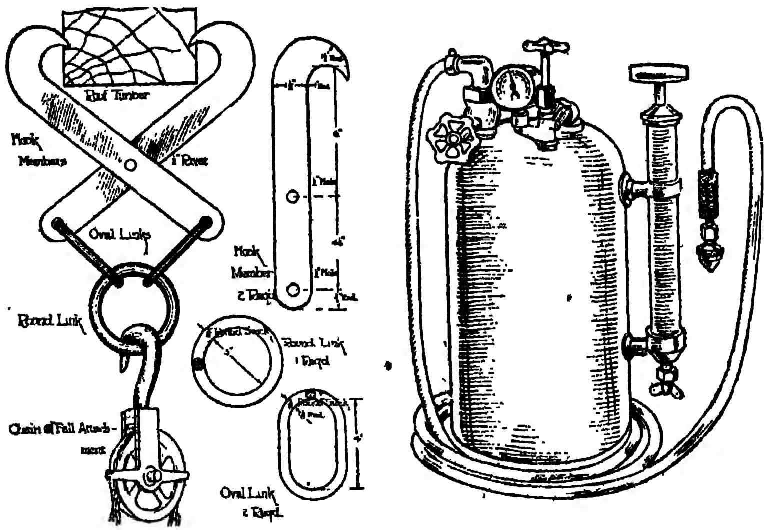


Fig. 40.—Outlining Construction of Supporting Member for Chain Fall Attachment and Appliance for Cleaning Machine Parts with a Gasoline Spray.

pieces to be brazed. Complete instructions for use of this and other forms of brazing appliances to be described will be found in chapter dealing with miscellaneous processes.

The utility of the chain falls has been previously considered, and it is somewhat a problem to provide a substantial method of supporting these in shops where the overhead trolley is not provided. The illustration at the left of Fig. 40 shows a very simple and strong supporting fixture for chain falls or other hoists and may be easily made by any repair shop mechanic in spare time. As

all parts of the device are clearly shown and dimensions given, further description is unnecessary.

One of the most disagreeable jobs incidental to repairing is cleaning the accumulation of oil, road dust or grease from parts to be worked on. The common method by means of a brush and gasoline is wasteful and time-consuming, and it is not possible to penetrate all corners thoroughly, as many of these are inaccessible. Gasoline or kerosene under pressure will remove dirt without using large quantities of liquid. A typical cleaning outfit is shown at the right of Fig. 40. This consists of a large receiver fitted with a pressure gauge and with a shut-off valve to which a hose connection is made. The tank is filled about half full of the cleansing liquid. The hand pump provided is used to force air pressure into the container in order to produce a spray of liquid having force enough to dislodge the particles of dirt. These are inexpensive and will save their cost in a short time by the saving in cleaning liquid.

In some large cities, notably New York, Chicago and Boston, there has been considerable agitation on the part of the municipal and insurance authorities toward the enactment of legislation making it compulsory for the automobile repair shop or garage proprietor to install separators attached to the floor drains in order to prevent volatile inflammable oils, such as gasoline, kerosene and lubricants from flowing into the sewer. A device which has been proposed by the New York authorities is shown at Fig. 41. It is built of boiler plate and standard pipe fittings and the proportions can be easily ascertained by inspection of the illustration. The floor drain is connected to the main drum upper portion and all water from the floor must flow into that chamber before it can pass into the sewer. As gasoline and lubricating oil are lighter than water, they will float on the top of that liquid and will drain off through the vertical stand pipe extending from the partition forming the top of the lower compartment to a point just above the water line. The lower compartment is provided with a gauge to show the height of liquid, a drain cock by which the lower compartment may be emptied and a large cleanout plug for the removal of sludge and residue that will not drain out through

the cock. A vent pipe extends from the lower compartment to the air in order to prevent the accumulation of any pressure due to gas generation from vaporization of the volatile liquids. The

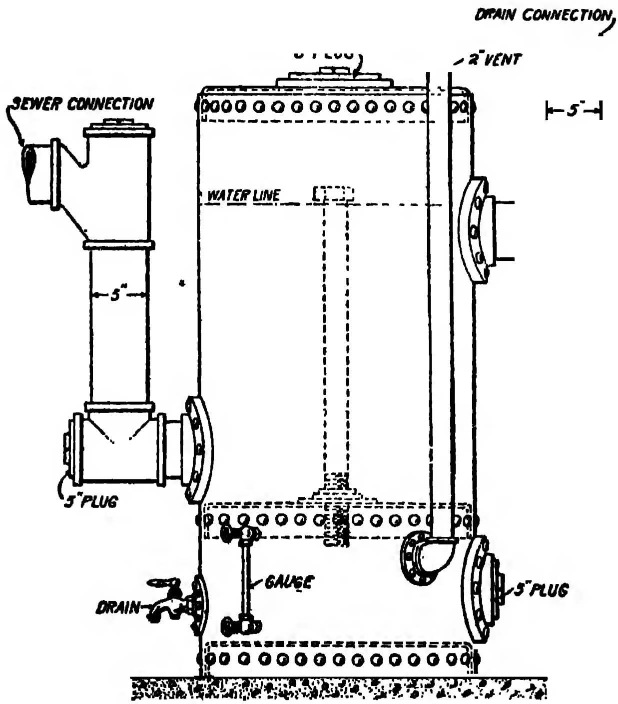


Fig. 41.—Separator Intended to Keep Volatile Inflammable Liquids from Entering City Sewers.

upper portion of the container and the pipe connections are also provided with cleanout plugs.

Another form of separator is shown at Fig. 42. This is marketed to meet the requirements of the fire and building departments of New York City and is known as the Paragon Separator. It is said that the best position for this device is near the side walk and

under the floor with a hand pump projecting through the floor. The waste water containing gasoline and oil enters the branch floor drain and flows into a sand box where all solid matter is extracted. From this point the liquid flows through a screen into a U-shaped container and then out through a discharge pipe into the street sewer. Inside the main portion of the U-shaped container is the cylindrical oil chamber in which the volatile liquids are collected.

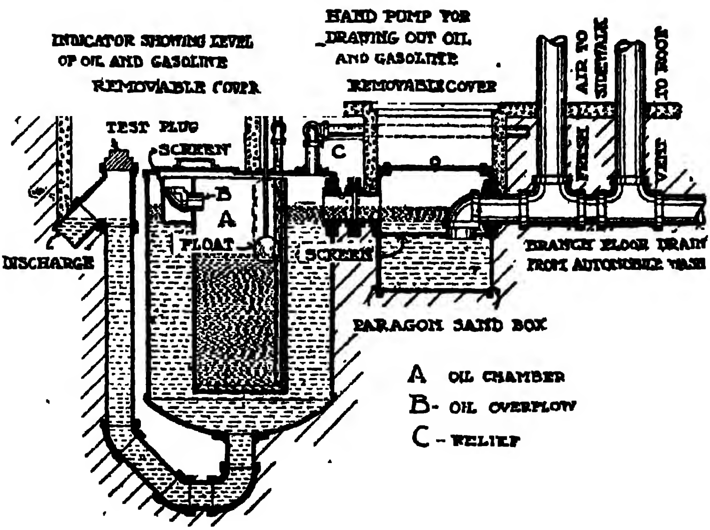


Fig. 42.—Another Form of Separator for Garage or Repair Shop Use.

As before stated, these are lighter than water and will float on the surface and thus enter the oil chamber through a suitable opening at the back of the cylinder. An indicator with a ball float shows the level of liquid in the oil chamber and when a sufficient quantity is indicated it may be drawn out by a hand pump. Two air vents are provided, one running to the roof for taking out the impure air, while another one runs to the sidewalk to let in fresh air which is heavier than that saturated with hydrocarbon vapor, thus driving it

out. The sand box is placed in a convenient position so to afford ready access when new filtering material is needed. Relief pipes are provided in both the U-shaped container and in the oil chamber to prevent the accumulation of any pressure in either of these portions of the separator.

Air Compressor Types.—All up-to-date repair shops, especially

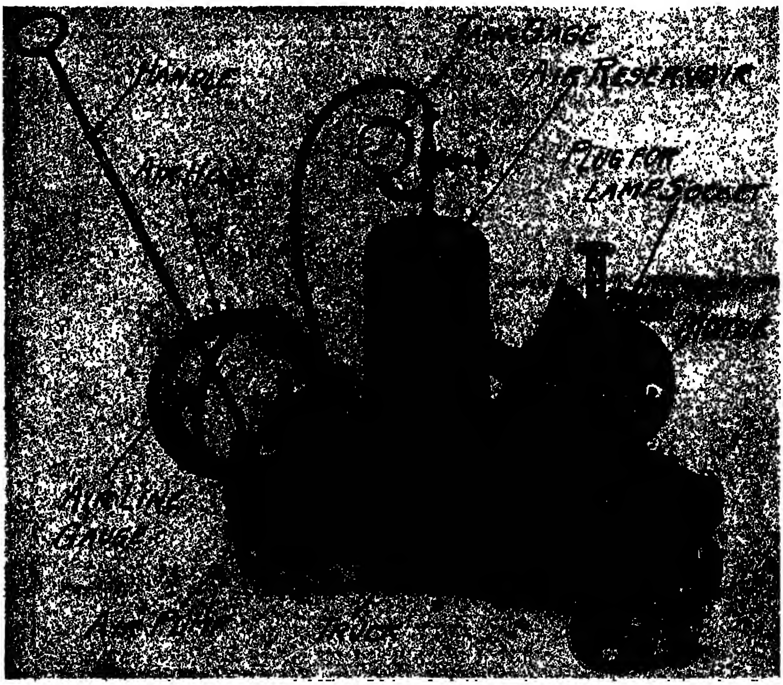


Fig. 43.—Portable Electrically Operated Air Compressor Outfit.

if they are an adjunct to a garage, or if they cater to tire repair work, have some power-driven source of compressed air. A blast of air has many uses besides that of filling pneumatic tires, as it can be used for blowing out loose carbon particles from the combustion chamber or light chips and steel fragments from gear boxes or rear axle housings. The air blast may also be used for cooling heated steel gradually when annealing it and can also be employed for

testing pipe joints, fuel containers, etc. The illustration at Fig. 43 shows a portable, electrically driven power pump suitable for public or private garages and repair shops. It is simple and compact in construction and as it is mounted on a wheeled base it can be easily drawn around the building or outside to the curb. A tank, 12 inches long and 6 inches in diameter, into which the pump discharges, prevents condensation and oil from entering and injuring the tire.

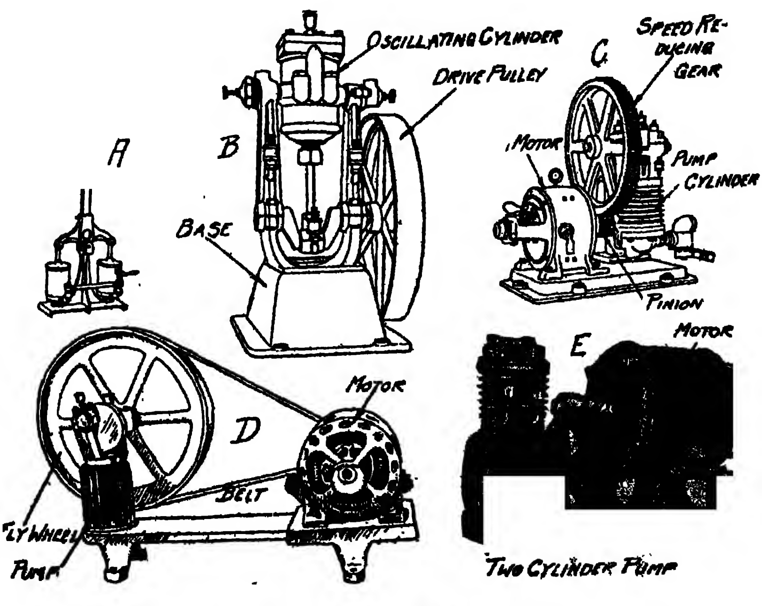


Fig. 44.—Conventional Forms of Air Compressors.

It is said that the pumping action is very rapid, as a 35 x 4 inch tire can be pumped from flat to 70 pounds pressure in one and one-half minutes. The motor is a Westinghouse, one and a quarter horse-power capacity, designed to operate from the lighting circuit and may be secured in any of the voltages commonly used.

A group of air compressors of different designs is shown at Fig. 44. That at A, is a powerful, hand operated double pump suitable for those garages and repair shops not provided with mechanical

power. It is operated through a lever which is sufficiently long it can be worked by one or two men standing upright. The form at B is a substantial power-driven compressor of large capacity having an oscillating cylinder. This type is used only in large repair shops where it is necessary to use a large air tank which must

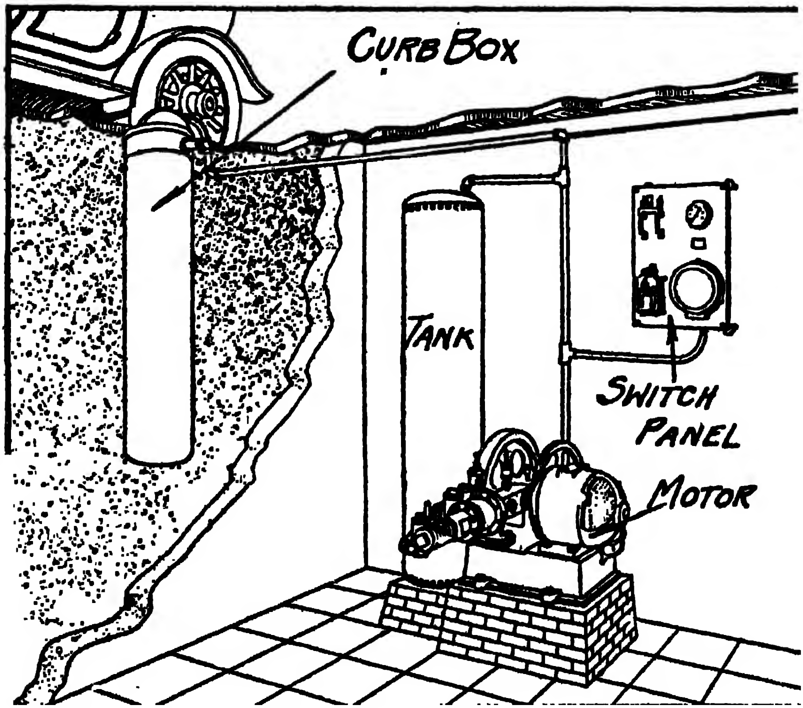


Fig. 45.—Sectional View Showing Hale Curb Box Installed with Automatic Air Compressor and Storage Tank.

be constantly filled. The air pump at C, has a vertical cylinder and is driven from an electric motor by means of a spur pinion on the armature shaft which meshes with a large gear on the pump crankshaft. This is attached to a substantial iron base and is intended to be bolted to the floor. A small portable power pump for use on the bench is shown at Fig. 44, D. This also is driven

by an electric motor, the power being transmitted from the armature by belt connection to the rim of a large flywheel-pulley attached to the crank disc of the pump. The outfit at E is similar in operation to that shown at C, except that a two cylinder air compressor is used. This is practically the same in general construction as the other forms illustrated, except that the use of two cylinders makes for a more steady flow of air.

A complete air compressor outfit provided with automatic regulating means and an apparatus to distribute air at the curb is shown at Fig. 45. This enables automobile owners to secure a supply of air without having to drive the car into the garage or dragging a portable air compressor outfit across the sidewalks. The accompanying diagram clearly shows the arrangement of this outfit. A tank is buried in the ground and this connects with the compressor outfit located in the basement. The lid of the curb box is flush with the sidewalk and in a few inches from the curb. The user raises the lid, takes out the hose and when the operation of tire inflation is complete, the hose returns to the box automatically when it is released. The air compressor installation consists of a reservoir or tank in the basement, an air compressor driven by an electric motor and a control panel. When the air pressure in the tank reaches a certain predetermined amount, an automatic switch breaks the circuit and the motor ceases to drive the pump. As soon as the pressure falls below the minimum allowable, the automatic switch again functions to close the circuit and start the pump going. In addition to the pipe leading to the curb box a branch pipe may be run to the garage interior and to the repair shop as well.

Liquid Fuel Storage.—The problem of liquid fuel storage is an important one for garages or repair shops, especially in cities where the municipal regulations pertaining to the storage of volatile hydrocarbons are severe. If the fuel is to be used only for shop purposes, either of the fuel storage systems shown at Fig. 46, A and B, will prove practical. That at A is the hydraulic system in which the gasoline stored in an underground tank is forced out by displacement, water flowing into the tank from the city main. The outfit at B also includes an under-

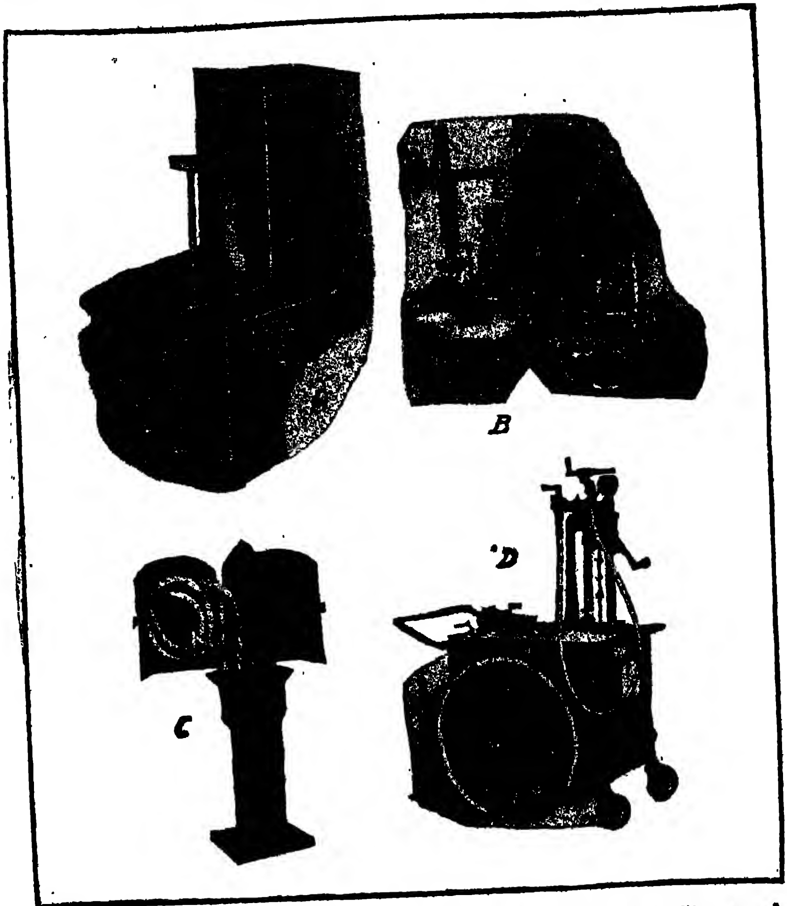


Fig. 46.—Methods of Liquid Fuel Storage Suitable for Repair Shops and Garages.

ground tank which is placed outside of the walls of the building, but the gasoline is drawn from the tank by a plunger pump. Where gasoline is sold to passing motorists two appliances that will promote quick service are shown at Fig. 46, C, and D. That at C, is a box designed to be placed outside of the garage or repair shop near the door or driveway so that cars do not need to run into the garage to be filled. This serves merely to support

a measuring pump drawing fuel from an underground tank and hose which will extend from the pump to the fuel container of the car. The outfit shown at D, consists of a rectangular tank mounted on wheels and having the usual form of measuring pump. This tank will hold several barrels of fuel, can be moved easily

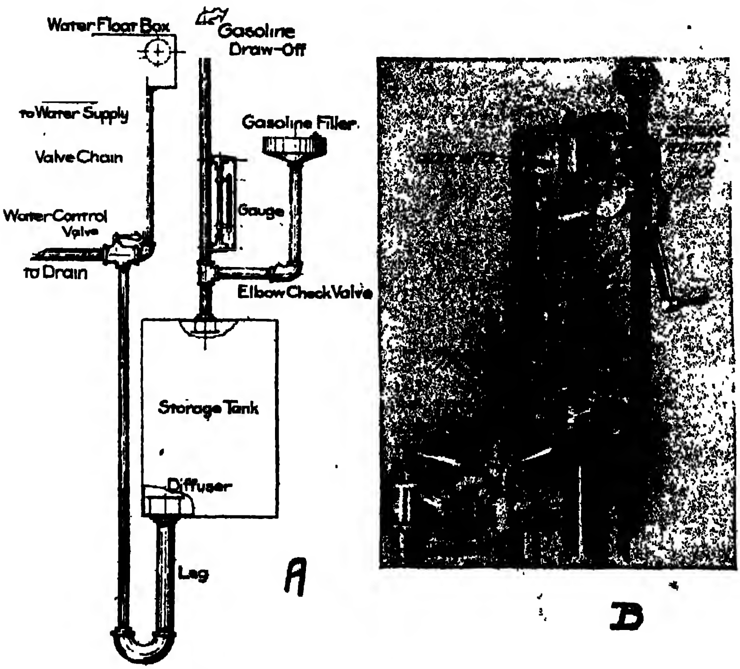


Fig. 47.—Outlining Two Practical Methods of Raising Liquid Fuel from Underground Tanks.

from place to place and the measuring pump insures that the liquid will be dispensed in proper quantities and without waste.

The principle of action of the hydraulic fuel supply system is shown at Fig. 47, A. The various parts comprising the assembly are clearly outlined. When it is desired to draw out gasoline it is merely necessary to open the water control valve which permits water to flow into the tank to displace the fuel. At Fig. 47, B, the

usual form of automatic measuring pump is shown. This is provided with a series of stops, so quantities varying from one pint to one gallon may be pumped by limiting the stroke of the pump. A two-way discharge is provided, one for filling cans, the other for attaching a supply hose to reach to the car tank. A meter is fitted

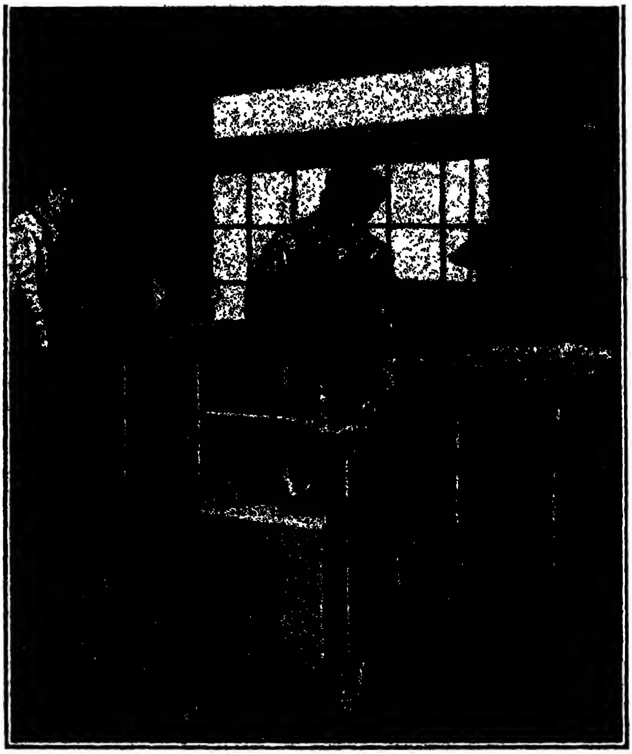


Fig. 48.—Showing Forge Equipment Suitable for Automobile Repair Shops.

that will indicate every gallon pumped. The pump plunger is actuated by a spur rack which is operated by a pinion turned by a hand crank. But little force is needed to operate this pump owing to the large leverage provided by the hand crank and the small pitch radius of the pinion.

Complete Forge Equipment Desirable.—Quite a number of repair jobs involve blacksmithing or brazing processes and two distinct forges should be installed. The usual equipment is a steel forge of medium size, with a power-driven rotary blower, to be used for forging and welding. For brazing, melting babbitt metal, hardening and tempering, annealing, and heating soldering irons a gas forge should be used, this taking its air from

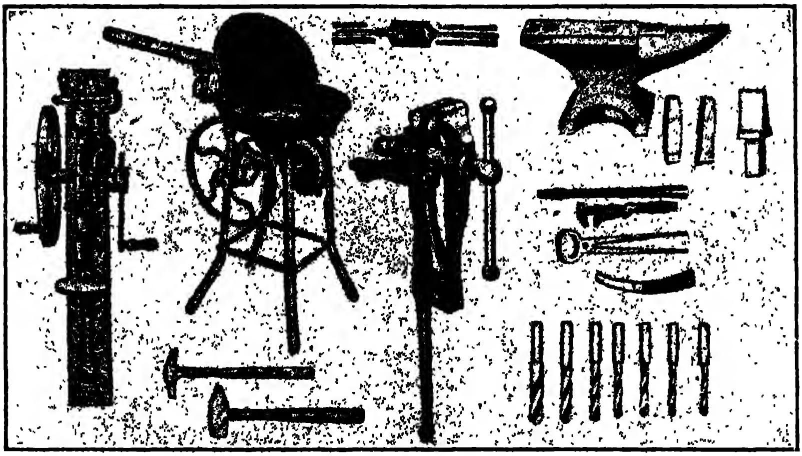


Fig. 49.—Complete Blacksmithing Outfit of Value in Small Repair Shop Equipment.

the tank of the air compressor outfit, and its gas from the city or town mains. In the smaller towns and villages the portable gasoline brazing forge can be used to advantage, providing that coal or water gas is not available. In the accompanying illustration, Fig. 48, a simple and practical forge outfit is shown, this including both gas and coal burning types. Between the coal and gas forge, a stout bench is usually erected, this having a strong vise and a large drawer. This bench can be used in both brazing and soldering processes, and the drawer can be divided into two compartments, one to hold the blacksmith tools, the other the soldering irons and sheet metal tools. The vise is handy to the workman at either forge. The remaining equipment is simple, a medium sized anvil, heavy

and medium sledge hammers, three or four forge hammers, tongs for holding round, flat and irregular work, cutting off tools or "hardies" for both cold and hot cutting and the flatting and swaging tools with handles of conventional patterns.

The gas forge shown is made of standard pipe and fittings, the table is a framework of iron pipe, across the top of which a piece of sheet steel serves to support ordinary firebrick against which the flame may be directed. A small hand torch is provided, this for use on the smaller brazing or soldering jobs. The melting ladles can be placed over either coal or gas flame, and either forge will melt the anti-friction metals used in lining bearing boxes.

The parts of a blacksmith's equipment for repair work that may be purchased as a complete outfit for around $50.00 are shown at Fig. 49. While two or three of the tools are intended for use in horseshoeing they can be employed to equally good advantage in the automobile repair shop. These consist of the farrier's hammer, knife and pincers. The remaining tools will be found suitable for use in general metal work. A post drill is provided which is a very practical tool for shops not provided with power. An outfit of drills in standard sizes is usually supplied with this tool. The forge is light and compact and a hand-operated blower is utilized to furnish the blast. A post vise, medium size, anvil, hand sledge and various small tools complete this set. In a shop already furnished with various machine tools the only parts of the outfit needed would be the forge, anvil and post vise. Tongs can be made as needed to best suit the requirements of the work at hand.

In large repair shops, where considerable tool dressing is done and where it is necessary to heat-treat various parts, the electric furnace shown at Fig. 50 will prove a good investment. The amount of heat may be regulated within close limits and sufficiently high temperatures may be obtained for hardening, carburizing or annealing any pieces within the range of the furnace. While it is not expected that a furnace of this type will be used in the small or medium size shops, there is sufficient work in the large establishments or service stations to warrant the installation of a furnace of this nature, if electric current is available, or an

equivalent gas, or oil-burning type where it is not convenient to use the electrically heated form. The almost universal use of high grade alloy steel in the construction of automobiles makes it necessary for the repairman to have some knowledge of heat treatment of the various special steels. They cannot be machined unless an-

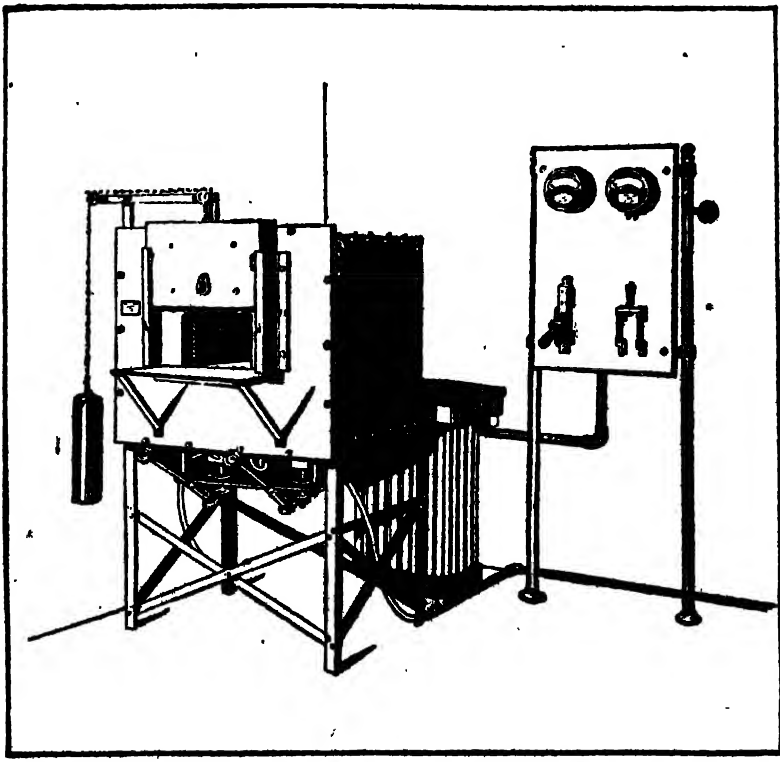


Fig. 50.—Electrically Heated Furnace for Heat Treating Steel.

nealed and are of but little more value than ordinary machiner steel parts if they are not properly heat-treated to bring out th physical characteristics desired after fabrication. A review of th various heat-treating processes, especially those needed for th different alloy steels used in automobile construction, will be foun in the chapter dealing with miscellaneous processes.

CHAPTER II.

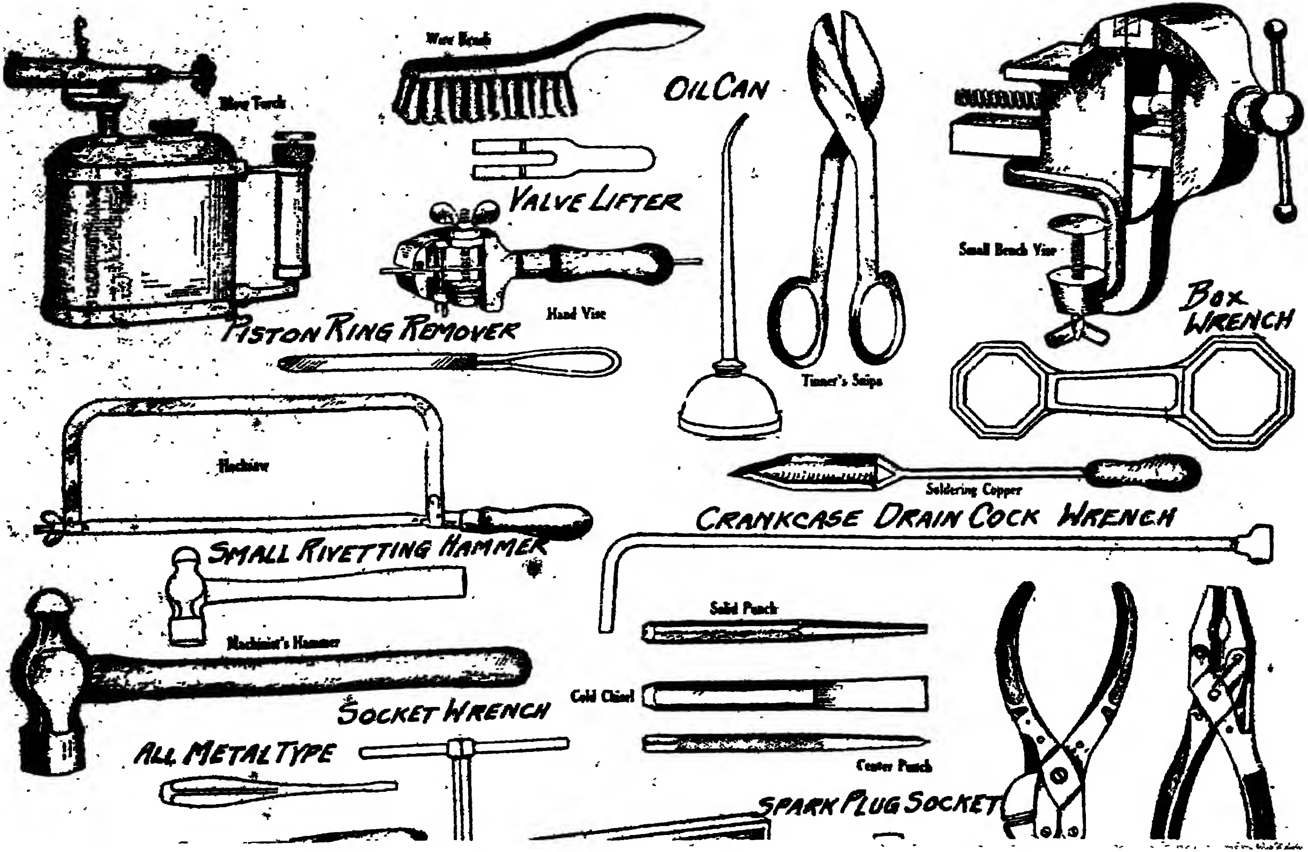
SMALL TOOL EQUIPMENT FOR REPAIR SHOPS

Tools for Adjusting and Erecting—Drilling Machines—Machine Accessories —Measuring Tools—Lathe Accessories and Lathe Tools—Miscellaneous Tools—Special Tools to Facilitate Repair Work—Wheel and Gear Pullers —List of Tools and Supplies for Typical Shop.

THERE are so many small items of equipment entering into the outfit necessary to carry on repair work economically and efficiently, and so many supplies are needed that it is difficult to distinguish between the tools used only on the car and others which serve a general purpose about the garage or repair shop. In the previous chapter the various forms of machine tools that have a place in the machine room equipment have been described, so in this chapter endeavor will be made to confine the discussion to the smaller tools used in assembling and dismantling automobiles as well as in making the necessary adjustments to the various machine parts.

Machine tools in themselves are of little value without an adequate supply of smaller tools to be used in connection with them. For example, a lathe could not be employed to advantage without a complete set of accessories and cutting tools, while a drilling machine would be valueless if not supplied with proper chucks and drills for making the holes. We will first consider the small tool equipment, such as would be used by automobilists or repairmen in making the everyday adjustments on the car, then the tools that are of special value to the machinist and lastly those special appliances which facilitate repair work and which usually can be made cheaper than they can be purchased.

Tools for Adjusting and Erecting.—A very complete outfit of small tools, some of which are furnished as part of the tool equip-



Blow Torch
Wire Brush
OIL CAN
VALVE LIFTER
Hand Vise
PISTON RING REMOVER
Tinner's Snips
Small Bench Vise
BOX WRENCH
Hacksaw
Soldering Copper
CRANKCASE DRAIN COCK WRENCH
SMALL RIVETTING HAMMER
Machinist's Hammer
Solid Punch
Cold Chisel
Center Punch
SOCKET WRENCH
ALL METAL TYPE
SPARK PLUG SOCKET

ment of various cars are shown in group at Fig. 51. This group includes all of the tools necessary to complete a very practical kit and it is not unusual for the floor man who is continually dismantling and erecting cars to possess even a larger assortment than indicated. The small bench vise provided is a useful auxiliary that can be clamped to the running board of the car and should have jaws at least three inches wide and capable of opening four or five inches. It is especially useful in that it will save trips to the bench vises and can also be carried as part of the tool equipment by the motorist to advantage, as it has adequate capacity to handle practically any of the small parts that need to be worked on when making repairs. A blow torch, tinner's snips and soldering copper are very useful in sheet metal work and in making any repairs requiring the use of solder. The torch can be used in any operation requiring a source of heat. The large box wrench shown under the vise is used for removing the wheel hub cap and sometimes has one end of the proper size to fit the valve chamber cap. The piston ring removers are easily made from thin strips of sheet metal securely brazed or soldered to a light wire handle. These are used in sets of three for removing and applying piston rings in a manner to be indicated in the next chapter. The uses of the wrenches, screw drivers, and pliers shown are known to all and the variety outlined should be sufficient for all ordinary work of restoration. The wrench equipment is very complete including a set of open end S-wrenches to fit all standard bolts, a spanner wrench, socket or box wrenches for bolts that are inaccessible with the ordinary type, adjustable end wrenches, a thin monkey wrench of medium size, a bicycle wrench for handling small nuts and bolts, a Stillson wrench for pipe and a large adjustable monkey wrench for the stubborn fastenings of large size.

Three different types of pliers are shown, one being a parallel jaw type with size cutting attachment, while the other illustrated near it is a combination parallel jaw type adapted for use on round work as well as in handling flat stock. The most popular form of pliers is the combination pattern shown beneath the socket wrench set. This is made of substantial drop forgings having a hinged joint that can be set so that a very wide opening at the

jaws is possible. These can be used on round work and for wire cutting as well as for handling flat work.

A very complete set of files, including square, half round,

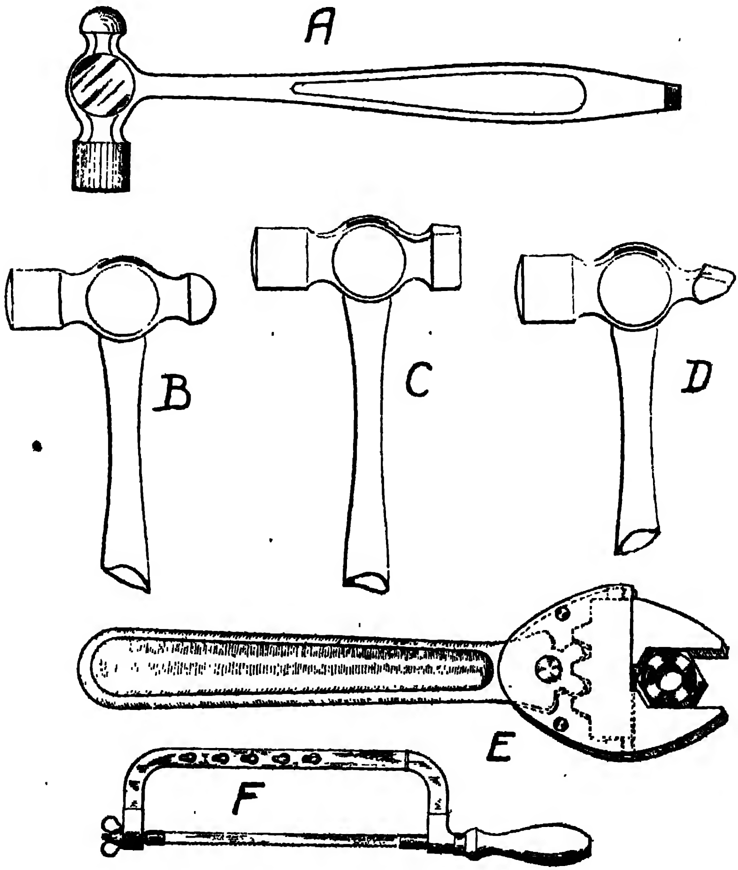


Fig. 52.—Forms of Hammers Suitable for the Automobile Repairman's Tool Kit.

mill, flat bastard, three-cornered and rat tail are also necessary. A hacksaw frame and a number of saws, some with fine teeth for tubing and others with coarser teeth for bar or solid stock will

be found almost indispensable. A complete punch and chisel set should be provided, samples of which are shown in the group while the complete outfit is outlined in another illustration. A number of different forms and sizes of chisels are necessary, as one type is not suitable for all classes of work. The adjustable end wrenches can be used in many places where a monkey wrench cannot be fitted and where it will be difficult to use a wrench having a fixed opening. The Stillson pipe wrench is useful in turning studs, round rods, and pipes that cannot be turned by any other means. A complete shop kit must necessarily include various sizes of Stillson and monkey wrenches, as no one size can be expected to handle the wide range of work the repairman must cope with. Three sizes of each form of wrench can be used, one, a 6 inch, is as small as is needed while a 12 inch tool will handle almost any piece of pipe or nut used in a motor car. For large work a 16 inch or 18 inch Stillson will be found of value.

Two or three sizes of hammers should be provided, according to individual requirement, these being small riveting, medium and heavyweight machinist's hammers. A very practical tool of this nature for the repair shop is shown at Fig. 52, A, as it can be used as a hammer, screw driver or tire iron. It is known as the "Spartan" hammer and is a tool steel drop forging in one piece having the working surfaces properly hardened and tempered while the metal is distributed so as to give a good balance to the head and a comfortable grip to the handle. The hammer head provides a positive and comfortable T-handle when the tool is used as a screw driver or tire iron. Machinist's hammers are provided with three types of heads, these being of various weights. That at B, is the form most commonly used and is termed the "ball pein" on account of the shape of the portion used for riveting. The straight pein shown at C, is just the same as the cross pein shown at D, except that in the latter the straight portion is at right angles to the hammer handle, while in the former it is parallel to that member.

A self-adjusting monkey wrench which is known as the "speed nut" is shown at Fig. 52, E. The act of pulling on the handle tightens the wrench on the nut by means of a rack which is formed

integral with the movable jaw and a portion of a pinion meshing with it at the end of the handle. Pulling on the handle tightens the wrench on the nut and the harder one pulls, the more securely the nut is gripped. As moving the handle in the opposite direction spreads the jaws apart, a sort of a ratchet action is possible if the

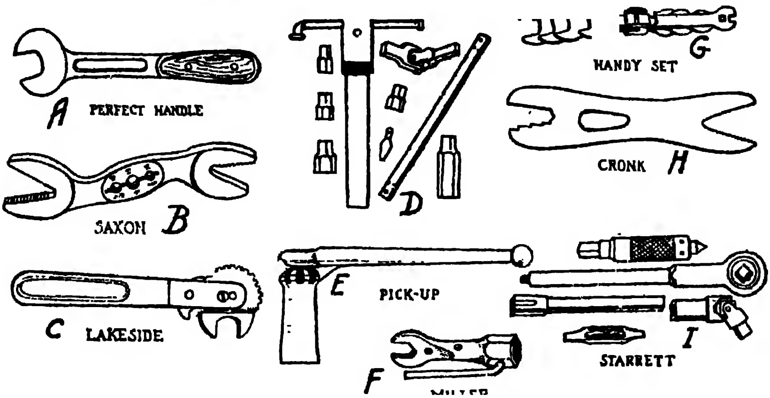


Fig. 53.—Wrenches are Offered in Many Forms.

handle is alternately pulled and pushed, rendering it unnecessary to take the wrench off and secure a new hold on the nut or bolt head for each turn. The wrench is composed of only three pieces and the smallest size will fit nuts varying from $1/4$-inch to $3/4$-inch. In order to unscrew a nut it is necessary to turn the wrench over so the handle will be pulled in the opposite direction to that used in screwing the nut down. This insures a secure grip in either case and permits of a ratchet motion without setting any trip or pawl. The hacksaw frame shown at Fig. 51, is a solid type adapted only to take one length of blade. As hacksaw blades are made in varying lengths it may be possible that a longer one than that frame was made for would be the only thing available. In such a case the adjustable hacksaw frame shown at Fig. 52, F, would permit of using a longer saw blade by merely extending the frame as far as is necessary.

Wrenches have been made in infinite variety and there are a score or more patterns of different types of adjustable socket and off-set wrenches. The various wrench types that differ from the more conventional monkey wrenches or those of the Stillson pattern are shown at Fig. 53. The "perfect handle" is a drop forged open end form provided with a wooden handle similar to that used on a monkey wrench in order to provide a better grip for the hand. The "Saxon" wrench is a double alligator form, so called because the jaws are in the form of a V-groove having one size of the V plain, while the other is serrated in order to secure a tight grip on round objects. In the form shown, two jaws of varying sizes are provided, one for large work, the other to handle the smaller rods. One of the novel features in connection with this wrench is the provision of a triple die block in the centre of the handle which is provided with three most commonly used of the standard threads including 5/16-inch-18, 3/8-inch-16, and 1/2-inch-13. This is useful in cleaning up burred threads on bolts before they are replaced, as burring is unavoidable if it has been necessary to drive them out with a hammer. The "Lakeside" wrench has an adjustable pawl engaging with one of a series of notches by which the opening may be held in any desired position.

Ever since the socket wrench was invented it has been a popular form because it can be used in many places where the ordinary open end or monkey wrench cannot be applied owing to lack of room for the head of the wrench. A typical set which has been made to fit in a very small space is shown at D. It consists of a handle, which is nickel plated and highly polished, a long extension bar, a universal joint and a number of case hardened cold drawn steel sockets to fit all commonly used standard nuts and bolt heads. Two screw driver bits, one small and the other large to fit the handle and a long socket to fit spark plugs are also included in this outfit. The universal joint permits one to remove nuts in a position that would be inaccessible to any other form of wrench as it enables the socket to be turned even if the handle is at one side of an intervening obstruction.

The "Pick-up" wrench shown at E, is used for spark plugs and the upper end of the socket is provided with a series of grooves

into which a suitable blade carried by the handle can be dropped. The handle is pivoted to the top of the socket in such a way that the blades may be picked up out of the grooves by lifting on the end of the handle and dropped in again when the handle is swung around to the proper point to get another hold on the socket. The "Miller" wrench shown at F, is a combination socket and open end type, made especially for use with spark plugs. Both the open end and the socket are the same size and either may be used as is the most convenient. The "Handy" set shown at G, consists of a number of thin stamped wrenches of steel held together in a group by a simple clamp fitting, which enables either end of any one of the four double wrenches to be brought into play according to the size of the nut to be turned. The "Cronk" wrench shown at H, is a simple stamping having an alligator opening at one end and a stepped opening capable of handling four different sizes of standard nuts or bolt heads at the other. Such wrenches are very cheap and are worth many times their small cost, especially for fitting nuts where there is not sufficient room to admit the more conventional pattern. The "Starrett" wrench set, which is shown at I, consists of a ratchet handle together with an extension bar and universal joint, a spark plug socket, a drilling attachment which takes standard square shank drills from 1/8-inch to 1/2-inch in diameter, a double ended screw driver bit and several adjustments to go with the drilling attachment. Twenty-eight assorted cold drawn steel sockets similar in design to those shown at D, to fit all standard sizes of square and hexagonal headed nuts are also included. The reversible ratchet handle, which may be slipped over the extension bar or the universal joint and which is also adapted to take the squared end of any one of the sockets is exceptionally useful in permitting, as it does, the instant release of pressure when it is desired to swing the handle back to get another hold on the nut. The socket wrench sets are usually supplied in hard wood cases or in leather bags so that they may be kept together and protected against loss or damage. With a properly selected socket wrench set, either of the ratchet handle or T-handle form, any nut on the car may be reached and end wrenches will not be necessary.

Mention has been previously made of the importance of provid ing a complete set of files and suitable handles. These should be in various grades or degrees of fineness and three of each kind should be provided. In the flat and half round files three grades

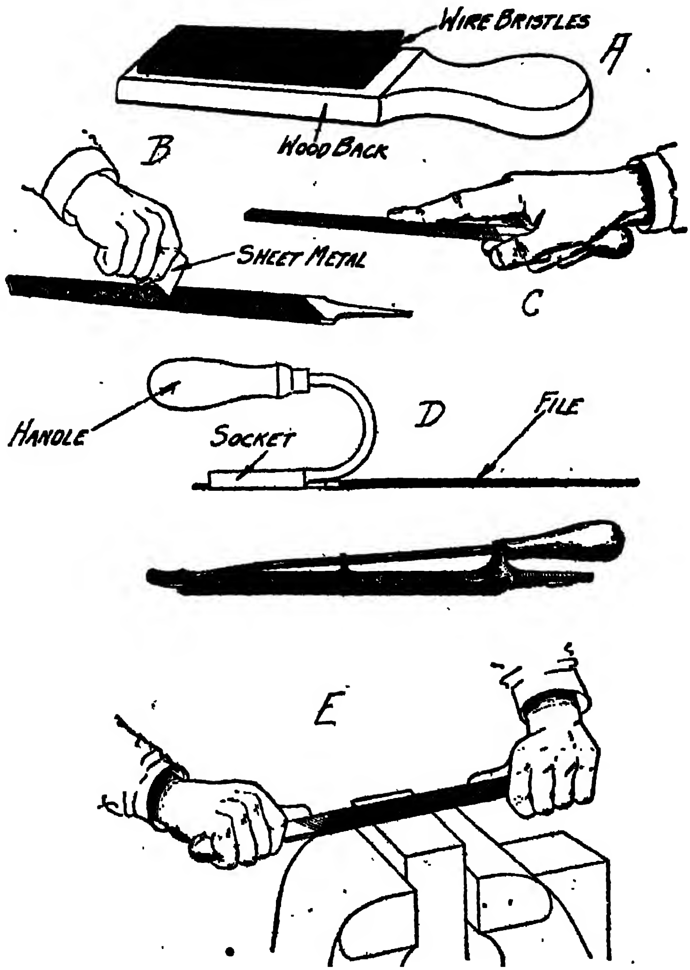


Fig. 54.—Illustrating Use and Care of Files.

are necessary, one with coarse teeth for roughing, and others with medium and fine teeth for the finishing cuts. The round or rat tail file is necessary in filing out small holes, the half round for finishing the interior of large ones. Half round files are also well adapted for finishing surfaces of peculiar contour, such as the inside of bearing boxes, connecting rod and main bearing caps, etc. Square files are useful in finishing keyways or cleaning out burred splines, while the triangular section or three-cornered file is of value in cleaning out burred threads and sharp corners. Flat files are used on all plane surfaces.

The file brush shown at 54, A, consists of a large number of wire bristles attached to a substantial wood back having a handle of convenient form so that the bristles may be drawn through the interstices between the teeth of the file to remove dirt and grease. If the teeth are filled with pieces of soft metal, such as solder or babbitt, it may be necessary to remove this accumulation with a piece of sheet metal as indicated at Fig. 54, B. The method of holding a file for working on plain surfaces when it is fitted with the regular form of wooden handle is shown at C, while two types of handles enabling the mechanic to use the flat file on plain surfaces of such size that the handle type indicated at C, could not be used on account of interfering with the surface finished are shown at D. The method of using a file when surfaces are finished by draw filing is shown at E. This differs from the usual method of filing and is only used when surfaces are to be polished and very little metal removed.

One of the most widely used of the locking means to prevent nuts or bolts from becoming loose is the simple split pin, sometimes called a "cotter pin." These can be handled very easily if the special pliers shown at Fig. 55, A, are used. These have a curved jaw that permits of grasping the pin firmly and inserting it in the hole ready to receive it. It is not easy to insert these split pins by other means because the ends are usually spread out and it is hard to enter the pin in the hole. With the cotter pin pliers the ends may be brought close together and as the plier jaws are small the pin may be easily pushed in place. Another use of this plier, also indicated, is to bend over the ends of the split pin in order to

prevent it from falling out. To remove these pins a simple curved lever, as shown at Fig. 55, B, is used. This has one end tapering to a point and is intended to be inserted in the eye of the cotter pin, the purchase offered by the handle permitting of ready re-

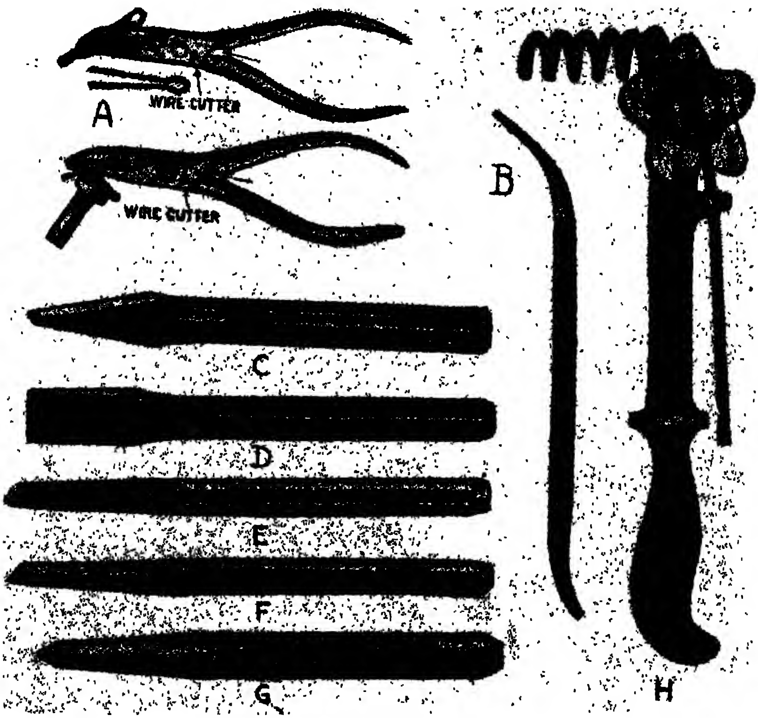


Fig. 55.—Outlining Use of Cotter Pin Pliers, Spring Winder and Showing Practical Outfit of Chisels.

moval of the pin after the ends have been closed by the cotter pin pliers.

A complete chisel set suitable for repair shop use is also shown at Fig. 55. The type at C, is known as a "cape" chisel and has a narrow cutting point and is intended to chip keyways, remove metal out of corners and for all other work where the broad cutting edge chisel, shown at D, cannot be used. The form with the

wide cutting edge is used in chipping, cutting sheet metal, etc. At E, a round nose chisel used in making oil ways is outlined, while a similar tool having a pointed cutting edge and often used for the same purpose is shown at F. The centre punch depicted at G, is very useful for marking parts either for identification or for drilling. In addition to the chisels shown, a number of solid punches or drifts resembling very much that shown at E, except that the point is blunt should be provided to drive out taper pins, bolts, rivets, and other fastenings of this nature. These should be pro-

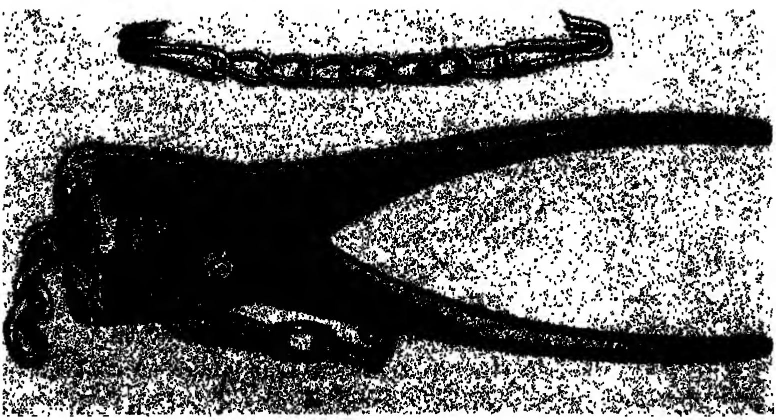


Fig. 56.—Special Pliers for Use in Repairing Weed Tire Chains.

vided in the common sizes. A complete set of real value would start at $1/8$-inch and increase by increments of 1/32-inch up to $1/2$-inch. A simple spring winder is shown at Fig. 55, H, this making it possible for the repairman to wind coil springs, either on the lathe or in the vise. It will handle a number of different sizes of wire and can be set to space the coils as desired.

Anti-skid chains form an important item in the equipment of the car and as they are subject to wear it is desirable to replace the worn cross chains with new ones from time to time, as some of these wear out quicker than others. A special pair of pliers having overlapping ends as shown at Fig. 56, is intended to assist in re-

moving and applying the cross chains. In order to remove the chains the hooked link at each end is spread apart by the wedging action of the plier jaws which make it possible to remove the cross chains from the side links. When a cross chain is to be applied the hooked link is placed near the fulcrum or hinge pin and the hooks may be bent down over the side chain by compressing the plier jaws.

If the automobile repairman was to provide himself with every

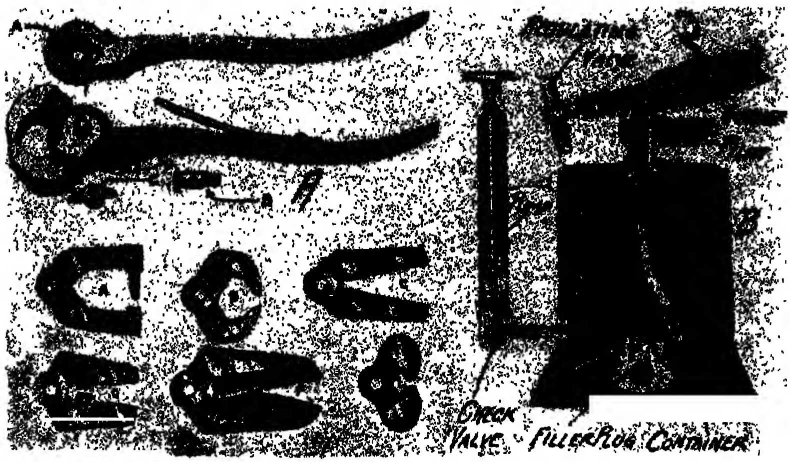


Fig. 57.—At Left, Useful Combination Pliers Having a Series of Interchangeable Heads; at Right, Sectional View Outlining Construction of Gasoline Blow Torch.

variety of tool that could be used to advantage, the investment in pliers alone would be large. This has resulted in the development of an interchangeable tool consisting of one standard pair of handles that will take a large variety of pliers, pincers and shears in the form of readily detachable heads which will fit the same handle. The change is readily made and a number of useful tools obtained without requiring a large investment. Samples of some of the most popular heads are shown at Fig. 56, below the handle That at A, is a leather or paper punch and may be obtained also

for punching metal. B, is a pincer head adapted for heavy work. The head at C, is an alligator form which can be adapted to a wide range of sizes. At D, a combination plier head is outlined, this consisting of flat nose, cutting and gas pipe pliers. At F, is shown a pair of tinner's snip blades to fit the handle. The head L, is used for working on Weed tire chains.

The tool is easily taken apart, the operation consisting of removing the wing nut C, from the centre bolt, lifting off the top part of the handle and then setting any desired head in the recess of each handle so the shank of the head is flush with the face of the handle. The square shank B, on the bolt is entered into the square hole A, in the top handle. After the two parts are together the wing nut C, is screwed down as tightly as possible. The bolt which holds the handles together, turns in the lower half, but cannot fall out. The object of this is to permit the lower half of the handle to turn on the bolt because on account of the square shank on the bolt and the square hole in the upper half of the handle, the bolt itself turns with this half, thereby preventing any possibility of the wing nut becoming loose in operation. This interchangeable tool is supplied in a neat box, having a place for the handle and the various heads supplied with it.

Mention has been previously made of the utility of the gasoline blow torch. A typical torch is shown in section at Fig. 57, B, in order that the internal construction may be readily understood. It consists of a main container of heavy sheet metal to which an air pump is attached at one side to act as a handle. The lower portion of this pump communicates with the interior of the tank by means of a bent pipe which deflects the air to the top of the fuel receptacle. The upper portion of the tank is supplied with a burner having a pipe leading to the bottom. A filling plug is inserted at the bottom of a conical depression which acts as a funnel when the torch is inverted for filling. The function of the air pump is to force air into the tank and displace the liquid fuel, forcing it to the burner where it is vaporized. The burner is of the Bunsen pattern and gives a blue flame. The intensity of the flame is regulated by a needle valve. In order to start the torch it is necessary to fill the pilot cup under burner with gaso-

line and to ignite same, letting it burn until the torch burner body is sufficiently heated to vaporize the liquid fuel. Three forms of these blow pipes are shown at Fig. 58. That at A, has a pump set into the tank and a more powerful burner that will give a very hot flame for brazing. The torch at B, has a flat fuel tank instead of the usual cylindrical form and has the filler opening at the top instead of at the bottom. The flat torch is easier to carry than the round ones because it occupies less space. A very small

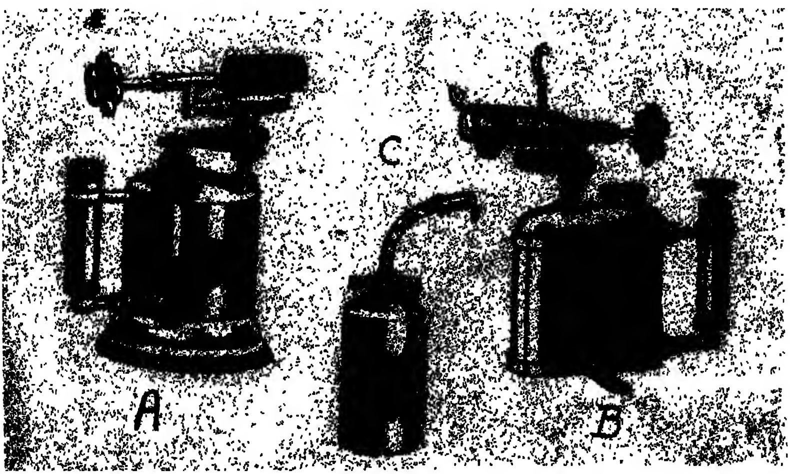


Fig. 58.—Practical Gasoline Blow Torches for Automobile Repair Work.

torch which needs no air pressure is shown at C. Sufficient heat to vaporize the fuel and to start the torch may be obtained by holding a match at the curved portion of the burner. This form does not produce the intense heat that the torches having internal air pressure do, but the flame is of sufficient intensity to heat a soldering iron, or perform any of the work incidental to soldering.

Drilling Machines.—Drilling machines may be of two kinds, hand or power operated. For drilling small holes in metal it is necessary to run the drill fast, therefore the drill chuck is usually driven by gearing in order to produce high drill speed without turning the handle too fast. A small hand drill is shown at Fig.

59, A. As will be observed, the chuck spindle is driven by a small bevel pinion, which in turn, is operated by a large bevel gear turned by a crank. The gear ratio is such that one turn of the handle will turn the chuck five or six revolutions. A drill of this design is not suited for drills any larger than one-quarter inch. For use with drills ranging from one-eighth to three-eighths, or even half-

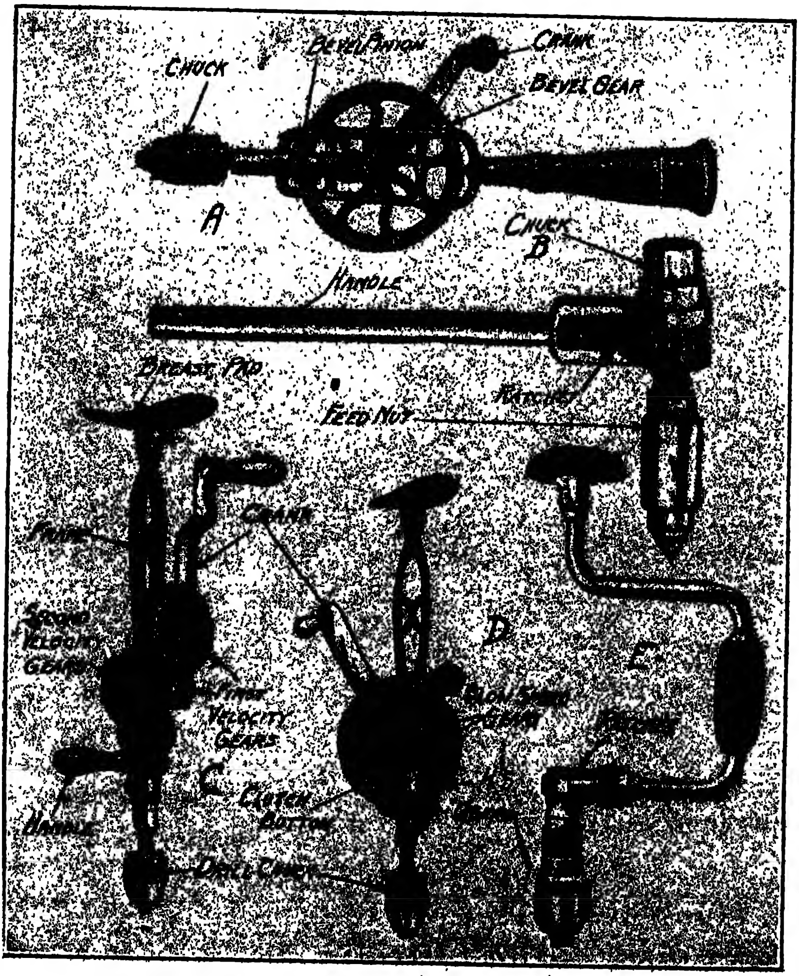


Fig. 59.—Forms of Hand Operated Drilling Machines.

inch the hand drill presses shown at C and D are used. These have a pad at the upper end by which pressure may be exerted with the chest in order to feed the drill into the work, and for this reason they are termed "breast drills." The form at C, has compound gearing, the drill chuck being driven by the usual form of bevel pinion in mesh with a larger bevel gear at one end of a countershaft. A small helical spur pinion at the other end of this countershaft receives its motion from a larger gear turned by the hand crank. This arrangement of gearing permits of high spindle speed without the use of large gears, as would be necessary if but two were used. The form at D, gives two speeds, one for use with small drills is obtained by engaging the lower bevel pinion with the chuck spindle and driving it by the large ring gear. The slow speed is obtained by shifting the clutch so that the top bevel pinion drives the drill chuck. As this meshes with a gear but slightly larger in diameter, a slow speed of the drill chuck is possible. Breast drills are provided with a handle screwed into the side of the frame, these are used to steady the drill press. For drilling extremely large holes which are beyond the capacity of the usual form of drill press the ratchet form shown at B, may be used or the bit brace outlined at E. The drills used with either of these have square shanks, whereas those used in the drill presses have round shanks. The bit brace is also used widely in wood work and the form shown is provided with a ratchet by which the bit chuck may be turned through only a portion of a revolution in either direction if desired.

One of the most difficult things to do in connection with installing accessories such as tire irons, license hangers, special lamp brackets, trunk racks, etc., is drilling holes in the pressed steel frame of the chassis, as the special alloy steel used for this purpose at the present time requires considerable exertion if one attempts to bore the hole with an ordinary breast drill. Electrically operated drills have a great advantage when used in making small holes but when they have sufficient capacity to take drills over ½-inch in diameter they are bulky to handle. These are of obvious utility when electrical current is available, but all shops are not so provided and many workmen do not like to use them because

of danger of shocks through short circuiting, or the liability of getting out of order, or of injuring the operator, should the drill point catch and the drill body be knocked out of the workman's hand. A handy tool that has many applications is shown at Fig.

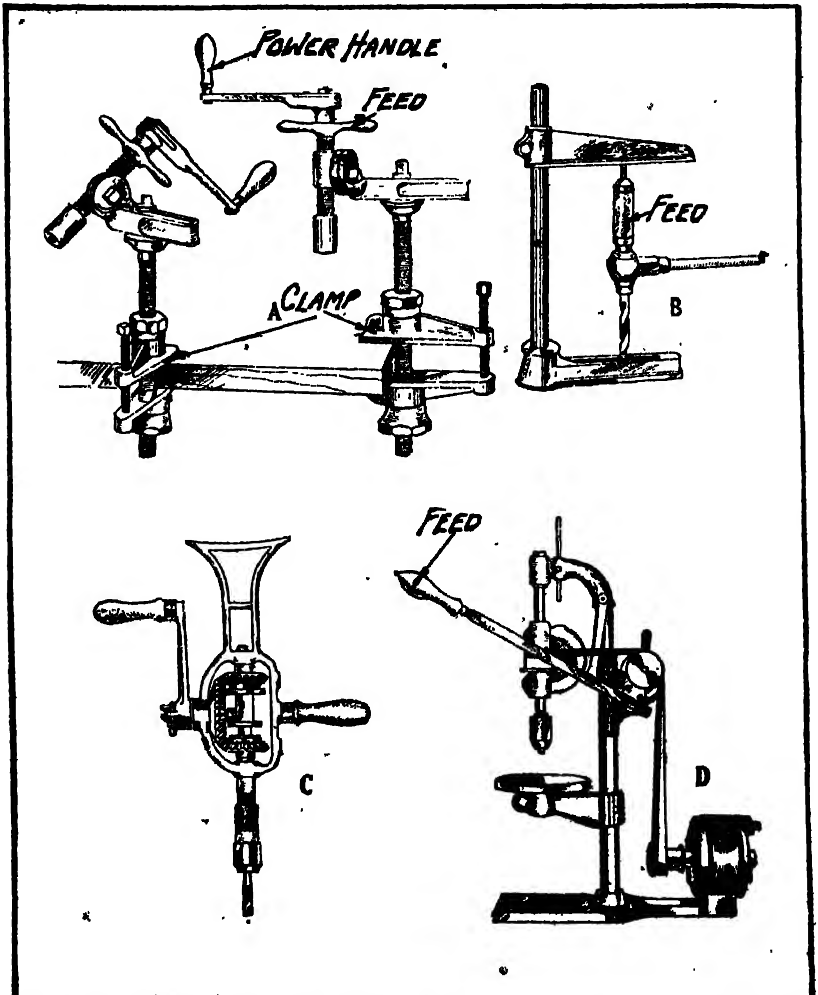


Fig. 60.—Showing Practical Application of Ratchet and Hand Feed Drilling Machines.

60, A. This is mounted on a clamp bracket, has a screw feed, can drill holes at any angle and offers a wide range of adjustment in all directions. These are made in three sizes, one taking any drill up to ⅝-inch, a medium size that can be used up to 1 inch in diameter and a larger model that will bore holes as large as 1¼ inches in diameter. The medium size tool will be found sufficiently large to answer the requirements of any repair shop. The chucks provided will take either square shank or standard taper shank drills. It will be evident that this fitting can be easily clamped to any part of the frame and that large holes may be drilled with ease on account of the leverage provided. A somewhat similar fixture is shown at Fig. 60, B, this being in use with the ratchet drill shown at Fig. 59, D. The fixture, which is known as the "old man" in repair shop parlance consists of a vertical post attached to a slotted base that can be clamped in any desired position by bolts or straps. The ratchet drill has a hand-operated screw feed and the arm against which the pressure of the drill is exerted may be raised, lowered or swung around to any desired position. A fitting of this nature may be used in connection with a wide variety of ratchet heads. The advantage of the ratchet arrangement is that it permits one to drill holes in places where it would not be possible to turn a hand drill as the lever can be oscillated through a small arc of a circle instead of a complete revolution. The special form of drill press shown at Fig. 60, C, can be changed over by a single trip from a drilling machine that will give a continual rotary motion to the chucks to a form that will give only an oscillating motion which is desirable in valve grinding. Another form of electrically operated sensitive drill press for the repairshop work-bench is shown at Fig 60, D. This differs in construction from that previously described in Chapter I, only in the method of drive which is by belt instead of friction discs.

Minor drilling operations with an ordinary hand drill are sometimes made difficult by the inability of the operator to hold the drill perfectly straight. The usual custom is to allow the head of the drilling tool to rest against the chest so that one hand may be used to get the brace straight and the other to turn the handle. This method requires much exertion, especially when a fixed piece

of metal is to be drilled and there is always a possibility of the hole being too large or drills breaking, due to swaying of the drill press. A very simple piece of apparatus described by Motor Age is shown at Fig. 61. This easily made jig enables the operator to keep the drill perfectly straight because one hand can be used to steady the drill. The jig is made of wood and of any convenient size to accommodate the particular drill press used. It

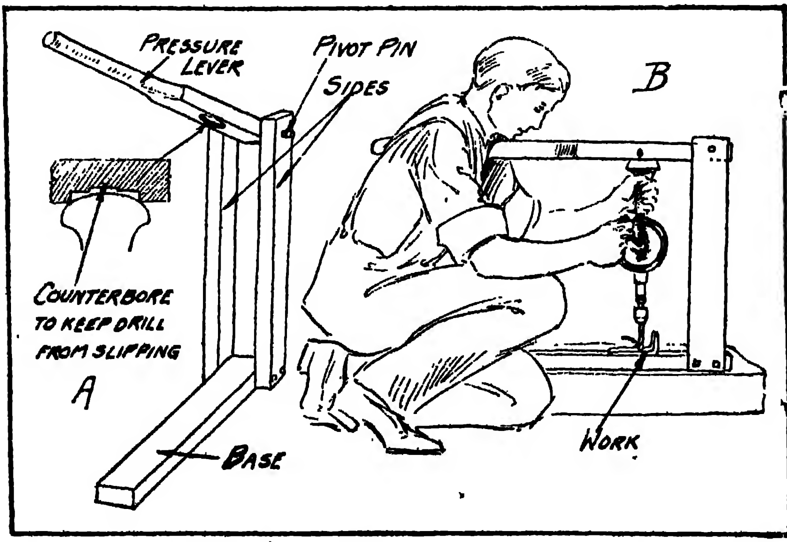


Fig. 61.—How to Use Hand Drills in Simple Homemade Drill Press.

consists of a block of wood forming a base with two uprights rigidly fastened to it by screws or bolts. These are drilled at their upper ends to take a piece of three-eighths inch steel rod which forms the fulcrum for the feed lever which is held under the arm, as the illustration clearly shows. A hole is drilled in the arm lever to take the head of the drill brace, as the detail shows, or if a breast drill is used instead of the hand drill, two pieces may be attached to keep the breast drill pad from turning, one at each side of that member. A drill press of this nature can be easily made from the odds and ends found in any repair shop and

is especially recommended to the motorist who likes to make his own mechanical repairs. The work to be operated on can be held in place by driving nails at the side or a simple vise to clamp the work may be readily extemporized.

Drills, Reamers, Taps and Dies.—In addition to the larger machine tools and the simple hand tools previously described, an essen-

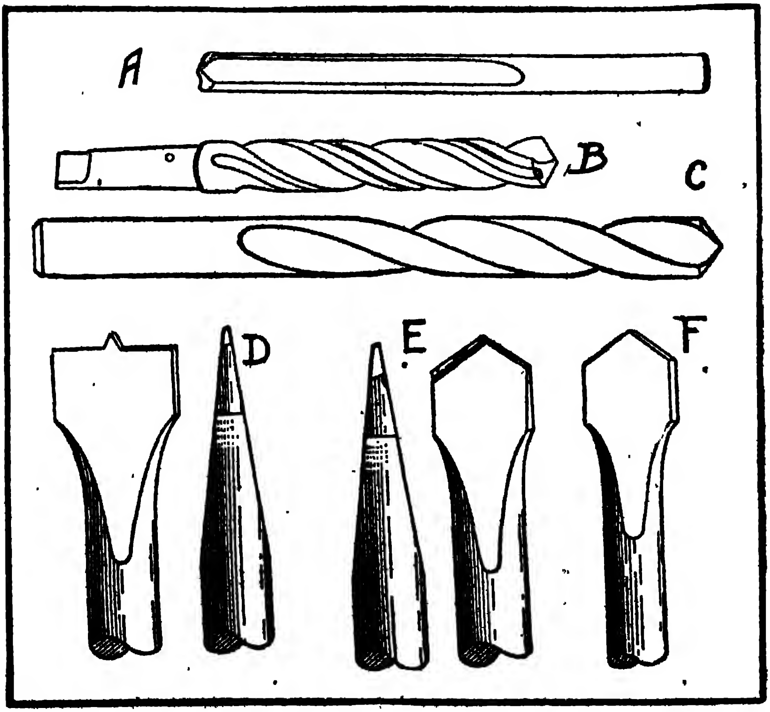


Fig. 62.—Forms of Drills Used in Hand and Power Drilling Machines.

tial item of equipment of any automobile repair shop, even in cases where the ordinary machine tools are not provided, is a complete outfit of drills, reamers, and threading tools. Drills are of two general classes, the flat and the twist drills. The flat drill has an angle between cutting edges of about 110 degrees and is usually made from special steel commercially known as drill rod.

A flat drill cannot be fed into the work very fast because it removes metal by a scraping, rather than a cutting process. The twist drill in its simplest form is cylindrical throughout the entire length and has spiral flutes which are ground off at the end to form the cutting lip and which also serve to carry the metal chips out of the holes. The simplest form of twist drill used is shown at Fig. 62, C, and is known as a "chuck" drill because it must be placed in a suitable chuck to turn it. A twist drill

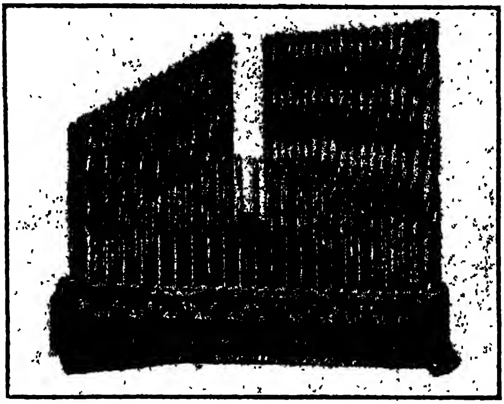


Fig. 63.—Useful Set of Number Drills, Showing Stand for Keeping These in an Orderly Manner.

removes metal by cutting and it is not necessary to use a heavy feed as the drill will tend to feed itself into the work.

Larger drills than $\frac{3}{4}$-inch are usually made with a tapered shank as shown at Fig. 62, B. At the end of the taper a tongue is formed which engages with a suitable opening in the collet, as the piece used to support the drill is called. The object of this tongue is to relieve the tapered portion of the drill from the stress of driving by frictional contact alone, as this would not turn the drill positively and the resulting slippage would wear the socket, this depreciation changing the taper and making it unfit for other drills. The tongue is usually proportioned so it is adequate to drive the drill under any condition. A small keyway is pro-

vided in the collet into which a tapering key of flat stock may be driven against the end of the tongue to drive the drill from the spindle. A standard taper for drill shanks generally accepted by the machine trade is known as the Morse and is a taper of five-eighths of an inch to the foot. The Brown and Sharp form tapers six-tenths of an inch to the foot. Care must be taken, therefore, when purchasing drills and collets, to make sure that the tapers coincide, as no attempt should be made to run a Morse taper in a Brown and Sharp collet, or vice versa.

Sometimes cylindrical drills have straight flutes, as outlined at Fig. 62, A. Such drills are used with soft metals and are of value when the drill is to pass entirely through the work. The trouble with a drill with spiral flutes is that it will tend to draw itself through as the cutting lips break through. This catching of the drill may break it or move the work from its position. With a straight flute drill the cutting action is practically the same as with the flat drill shown at Fig. 62, E and F.

If a drill is employed in boring holes through close-grained, tough metals, as wrought or malleable iron and steel, the operation will be facilitated by lubricating the drill with plenty of lard oil or a solution of soda and water. Either of these materials will effectually remove the heat caused by the friction of the metal removed against the lips of the drill, and the danger of heating the drill to a temperature that will soften it by drawing the temper is minimized. In drilling large or deep holes it is good practice to apply the lubricating medium directly at the drill point. Special drills of the form shown at Fig. 62, D, having a spiral oil tube running in a suitably formed channel, provides communication between the point of the drill and a suitable receiving hole on a drilled shank. The oil is supplied by a pump and its pressure not only promotes positive circulation and removal of heat, but also assists in keeping the hole free of chips. In drilling steel or wrought iron, lard oil applied to the point of the drill will facilitate the drilling, but this material should never be used with either brass or cast iron. Tables will be found in the last chapter giving drill speeds and feeds and other data relative to the use of this tool.

The sizes to be provided depend upon the nature of the work and the amount of money that can be invested in drills. It is common practice to provide a set of drills, such as shown at Fig. 63, which are carried in a suitable metal stand, these being known as number drills on account of conforming to the wire gauge standards. Number drills do not usually run higher than 5/16 inch in diameter. Beyond this point drills are usually sold by the diameter. A set of chuck drills ranging from 1/8 to 3/4 inch, advancing by 1/32 inch, and a set of Morse taper shank drills ranging from 3/4 to 1 1/4 inches, by increments of 1/16 inch, will be all that is needed for the most pretentious repair shop, as it is cheaper to bore holes larger than 1 1/4 inches with a boring tool than it is to carry a number of large drills in stock that would be used very seldom, perhaps not enough to justify their cost.

In grinding drills, care must be taken to have the lips of the same length, so that they will form the same angle with the axis. If one lip is longer than the other, as shown in the flat drill at Fig. 62, E, the hole will be larger than the drill size, and all the work of cutting will come upon the longest lip. The drill ends should be symmetrical, as shown at Fig. 62, F.

It is considered very difficult to drill a hole to an exact diameter, but for most work a variation of a few thousandths of an inch is of no great moment. Where accuracy is necessary, holes must be reamed out to the required size. In reaming, a hole is drilled about 1/32 inch smaller than is required, and is enlarged with a cutting tool known as the reamer. Reamers are usually of the fluted form shown at Fig. 64, A. Tools of this nature are not designed to remove considerable amounts of metal, but are intended to augment the diameter of the drill hole by only a small fraction of an inch. Reamers are tapered slightly at the point in order that they will enter the hole easily, but the greater portion of the fluted part is straight, all cutting edges being parallel. Hand reamers are made in either the straight or taper forms, that at A, Fig. 64, being straight, while B has tapering flutes. They are intended to be turned by a wrench similar to that employed in turning a tap, as shown at Fig. 66, C. The reamer shown at Fig. 64, C, is a hand reamer of the taper form widely used by

blacksmiths. The form at D has spiral flutes similar to a twist drill, and as it is provided with a taper shank it is intended to be turned by power through the medium of a suitable collet.

As the solid reamers must become reduced in size when sharpened, various forms of inserted blade reamers have been designed.

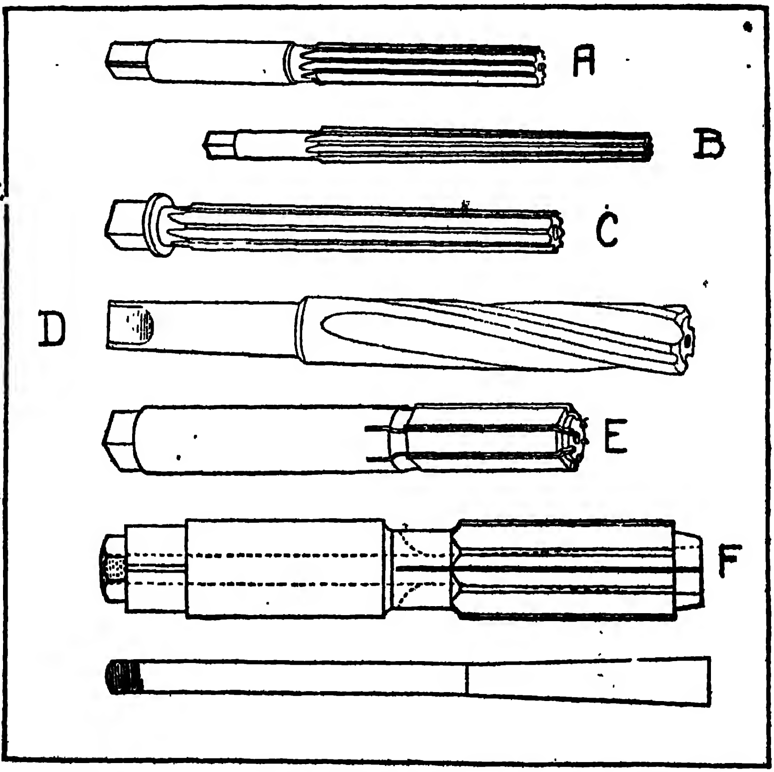


Fig. 64.—Illustrating Standard Forms of Hand and Machine Reamers.

One of these is shown at Fig. 64, E, and as the cutting surfaces become reduced in diameter it is possible to replace the worn blades with others of proper size. Expanding reamers are of the form shown at Fig. 64, F. These have a bolt passing through that fits into a tapering hole in the interior of the split reamer portion of

the tool. If the hole is to be enlarged a few thousandths of an inch, it is possible to draw up on the nut just above the squared end of the shank, and by drawing the tapering wedge farther into the reamer body, the cutting portion will be expanded and will cut a larger hole.

Reamers must be very carefully sharpened or there will be a

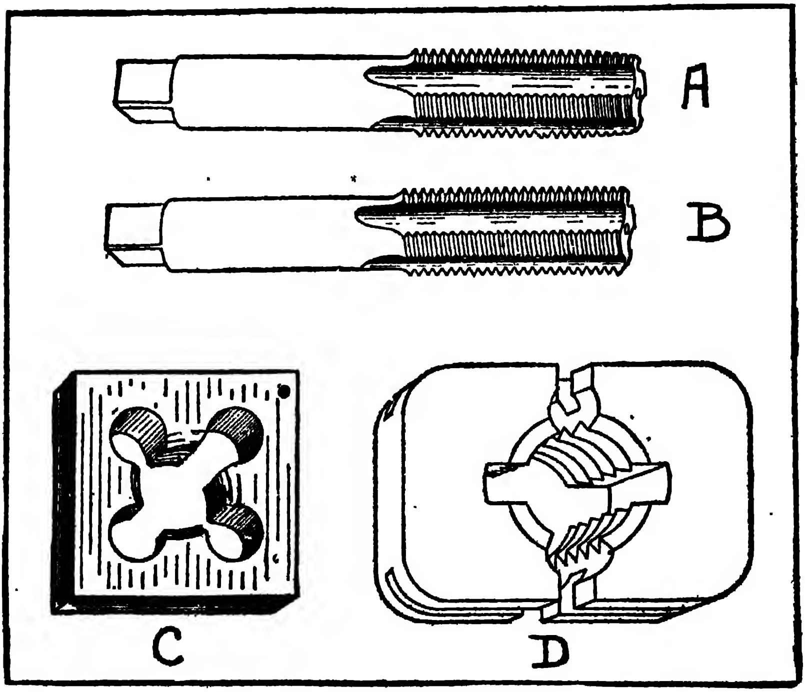


Fig. 65.—Tools for Thread Cutting.

tendency toward chattering with a consequent production of a rough surface. There are several methods of preventing this chattering, one being to separate the cutting edges by irregular spaces, while the most common method, and that to be preferred on machine reamers, is to use spiral flutes, as shown at Fig. 64, D. Special taper reamers are made to conform to the various taper pin sizes which are widely used in holding parts together in an

automobile. A taper of $\frac{1}{16}$ inch per foot is intended for holes where a pin, once driven in, is to remain in place. When it is desired that the pin be driven out, the taper is made steeper, generally $\frac{1}{4}$ inch per foot, which is the standard taper used on taper pins.

When threads are to be cut in a small hole, it will be apparent that it will be difficult to perform this operation economically on a lathe, therefore when internal threading is called for, a simple device known as a "tap" is used. There are many styles of taps, all conforming to different standards. Some are for metric or foreign threads, some conform to the American standards, while others are used for pipe and tubing. Hand taps are the form most used in repair shops, these being outlined at Fig. 65, A and B. They are usually sold in sets of three, known respectively as taper, plug, and bottoming. The taper tap is the one first put into the hole, and is then followed by the plug tap which cuts the threads deeper. If it is imperative that the thread should be full size clear to the bottom of the hole, the third tap of the set, which is straight-sided, is used. It would be difficult to start a bottoming tap into a hole because it would be larger in diameter at its point than the hole. The taper tap, as shown at A, Fig. 65, has a portion of the cutting lands ground away at the point in order that it will enter the hole. The manipulation of a tap is not hard, as it does not need to be forced into the work, as the thread will draw it into the hole as the tap is turned. The tapering of a tap is done so that no one thread is called upon to remove all of the metal, as for about half way up the length of the tap each succeeding thread is cut a little larger by the cutting edge until the full thread enters the hole. Care must be taken to always enter a tap straight in order to have the thread at correct angles to the surface.

In cutting external threads on small rods or on small pieces, such as bolts and studs, it is not always economical to do this work in the lathe, especially in repair work. Dies are used to cut threads on pieces that are to be placed in tapped holes that have been threaded by the corresponding size of tap. Dies for small work are often made solid, as shown at Fig. 66, C, but solid dies

are usually limited to sizes below ½ inch. Sometimes the solid die is cylindrical in shape, with a slot through one side which enables one to obtain a slight degree of adjustment by squeezing the slotted portion together. Large dies, or the sizes over ½ inch, are usually

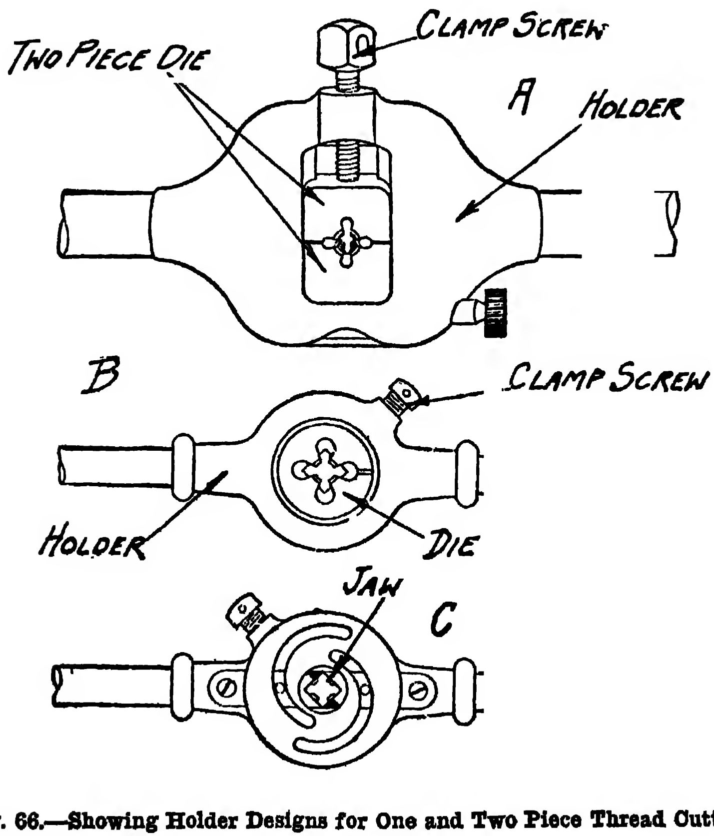


Fig. 66.—Showing Holder Designs for One and Two Piece Thread Cutting Dies.

made in two pieces in order that the halves may be closed up or brought nearer together. The advantage of this form of die is that either of the two pieces may be easily sharpened, and as it may be adjusted very easily the thread may be cut by easy

stages. For example, the die may be adjusted to cut large, which will produce a shallow thread that will act as an accurate guide when the die is closed up and a deeper thread cut.

A common form of die holder for an adjustable die is shown at Fig. 66, A. As will be apparent, it consists of a central body portion having guide members to keep the die pieces from falling out and levers at each end in order to permit the operator to exert sufficient force to remove the metal. The method of adjusting the depth of thread with a clamp screw when a two-piece die is employed is also clearly outlined. The diestock shown at B

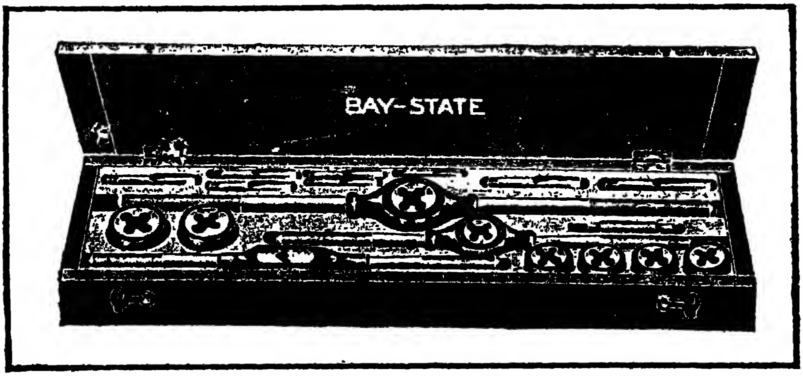


Fig. 67.—Useful Outfit of Taps and Dies for the Automobile Repair Shop.

is used for the smaller dies of the one-piece pattern, having a slot in order that they may be closed up slightly by the clamp screw. The reverse side of the diestock shown at B is outlined below it, and the guide pieces, which may be easily moved in or out, according to the size of the piece to be threaded by means of eccentrically disposed semi-circular slots in the adjustment plate, are shown. These movable guide members have small pins let into their surface which engage the slots, and they may be moved in or out, as desired, according to the position of the adjusting plate. The use of the guide pieces makes for accurate positioning or centering of the rod to be threaded. Dies are usually sold in sets, and are commonly furnished as a portion of a complete outfit

such as outlined at Fig. 67. That shown has two sizes of die-stock, a tap wrench, eight assorted dies, eight assorted taps, and a small screw driver for adjusting the die. An automobile repair shop should be provided with three different sets of taps and dies, as three different standards for the bolts and nuts are used in fastening automobile components. These are the American, metric (used on foreign cars), and the S. A. E. standard threads. A set of pipe dies and taps will also be found useful.

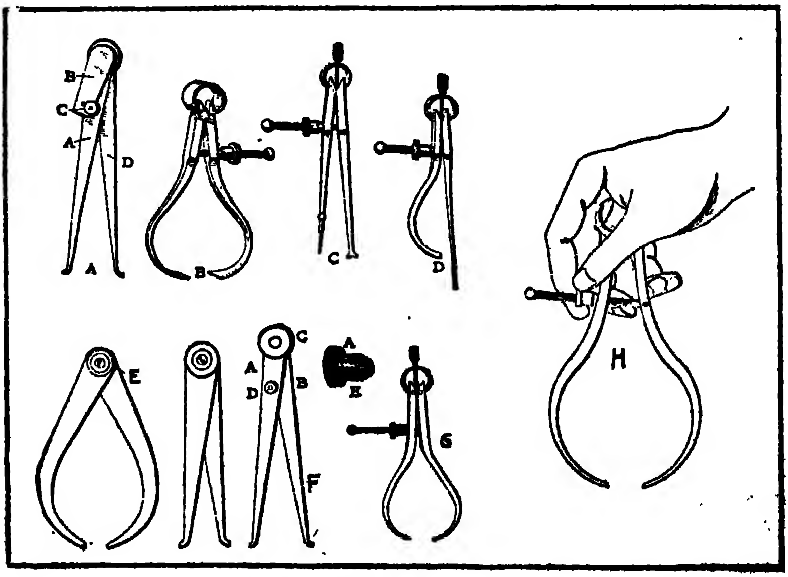


Fig. 68.—Common Forms of Inside and Outside Calipers.

Measuring Tools.—The tool outfit of the machinist or the mechanic who aspires to do machine work must include a number of measuring tools which are not needed by the floor man or one who merely assembles and takes apart the finished pieces. The machinist who must convert raw material into finished products requires a number of measuring tools, some of which are used for taking only approximate measurements, such as calipers and scales, while others are intended to take very accurate meas-

urements, such as the Vernier and the micrometer. A number of common forms of calipers are shown at Fig. 68. These are known as inside or outside calipers, depending upon the measurements they are intended to take. That at A is an inside caliper, consisting of two legs, A and D, and a gauging piece, B, which can be locked

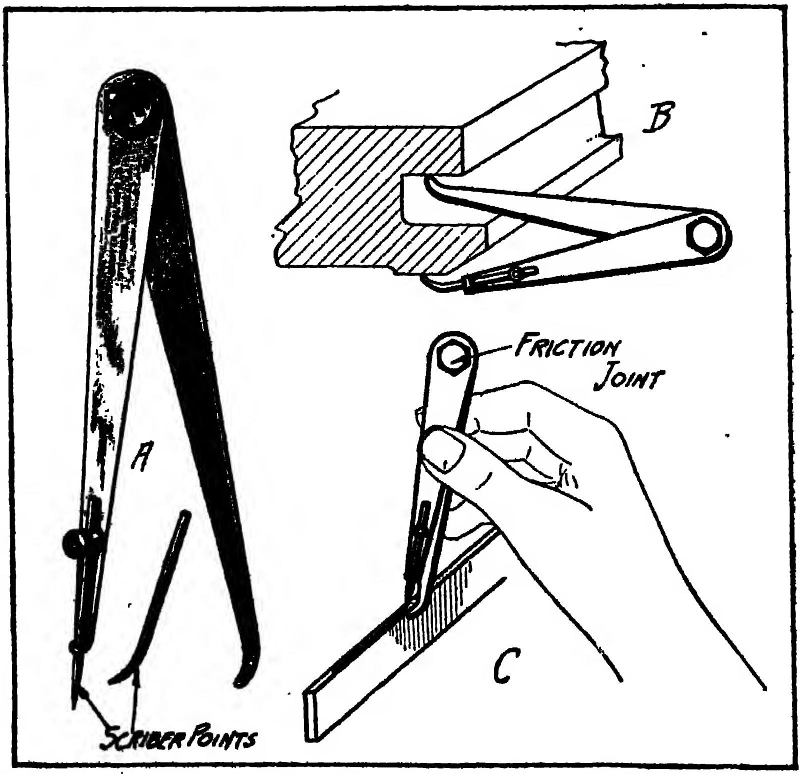


Fig. 69.—View Showing Utility of Combination Inside and Outside Friction Joint Calipers.

to leg, A, or released from that member by the screw, C. The object of this construction is to permit of measurements being taken at the bottom of a two diameter hole, where the point to be measured is of larger diameter than the portion of the hole through which the calipers entered. It will be apparent that the legs

A and D must be brought close together to pass through the smaller holes. This may be done without losing the setting, as the guide bar B will remain in one position as determined by the size of the hole to be measured, while the leg A may be swung in to clear the obstruction as the calipers are lifted out. When it is desired to ascertain the measurements the leg A is pushed back into place into the slotted portion of the guide B, and locked by the clamp screw C. A tool of this form is known as an internal transfer caliper.

The form of caliper shown at B is an outside caliper. Those at C and D are special forms for inside and outside work, the former being used, if desired, as a divider, while the latter may be employed for measuring the walls of tubing. The calipers at E are simple forms, having a friction joint to distinguish them from the spring calipers shown at B, C and D. In order to permit of ready adjustment of a spring caliper, a split nut as shown at G is sometimes used. A solid nut caliper can only be adjusted by screwing the nut in or out on the screw, which may be a tedious process if the caliper is to be set from one extreme to the other several times in succession. With a slip nut as shown at G it is possible to slip it from one end of the thread to the other without turning it, and of locking it in place at any desired point by simply allowing the caliper leg to come in contact with it. The method of adjusting a spring caliper is shown at Fig. 68, H. The caliper shown at Fig. 69, A, is known as a "hermaphrodite," and is so called because it can be used for measuring both diameters of pieces or bores of holes. It is provided with a removable and adjustable point, two being provided with each device. One of these is curved, the other is straight. The point is firmly held in position by a knurled nut and washer and draw bolt, and is given additional support by the loop at the end of the caliper leg. The auxiliary caliper point furnished with these tools makes it possible to convert the tools readily into an inside caliper. Two uses of this tool are shown at Fig. 69, B and C. These are self-explanatory.

An important tool that should be included in the equipment of every shop where machine tools are used is shown at Fig. 70, A.

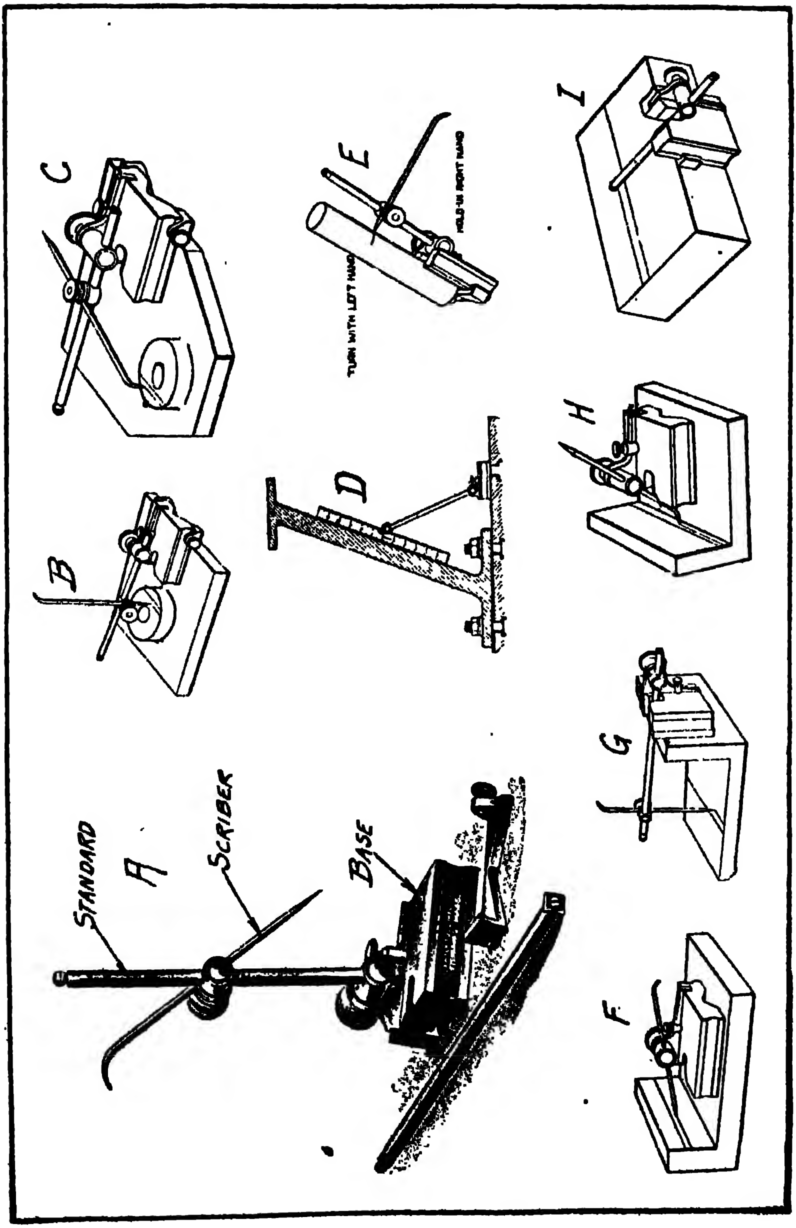


Fig. 70.—Illustrating Typical Surface Gauge and Methods of Using.

This is used in connection with the surface plate or the bed of a drill press or planer, and will serve many purposes. The tool shown is provided with three spindles ranging from nine to eighteen inches in length, and the construction admits of swinging the standard three-quarters of the distance around the base. The adjusting mechanism is so arranged that it can be set at any desired position. The clamping devices are rigid and firm and are not susceptible to slipping. The application at B shows the use in laying out lines on the boss of a casting where the scriber point can be placed directly over the boss. The application at C shows the method of making these lines where the scriber point support must be offset and placed at some distance from the boss to be marked. At D the surface gauge is shown used in connection with a scale in order to make measurements and secure the alignment of an angular I section casting. At E the method of scribing a line around a piece of barstock or tube is shown. The remaining illustrations show the uses of the surface gauge in laying out work of various kinds. Many other combinations are possible besides those shown, as a tool of this nature can be used as a bench gauge, scribing block or depth gauge.

Among the most common of the machinist's tools are those used for linear measurements. The usual forms are shown in group, Fig. 71. The most common tool, which is widely known, is the carpenter's folding two-foot rule or the yardstick. While these are very convenient for taking measurements where great accuracy is not required, the machinist must work much more accurately than the carpenter, and the standard steel scale which is shown at Fig. 71, D, is a popular tool for the machinist. The steel scale is in reality a graduated straight edge and forms an important part of various measuring tools. These are made of high grade steel and vary from 1 to 48 inches in length. They are carefully hardened in order to preserve the graduations, and all surfaces and edges are accurately ground to insure absolute parallelism. The graduations on the high grade scales are produced with a special device known as a dividing engine, but on cheaper scales, etching suffices to provide a fairly accurate graduation. The steel scales may be very thin and flexible, or may

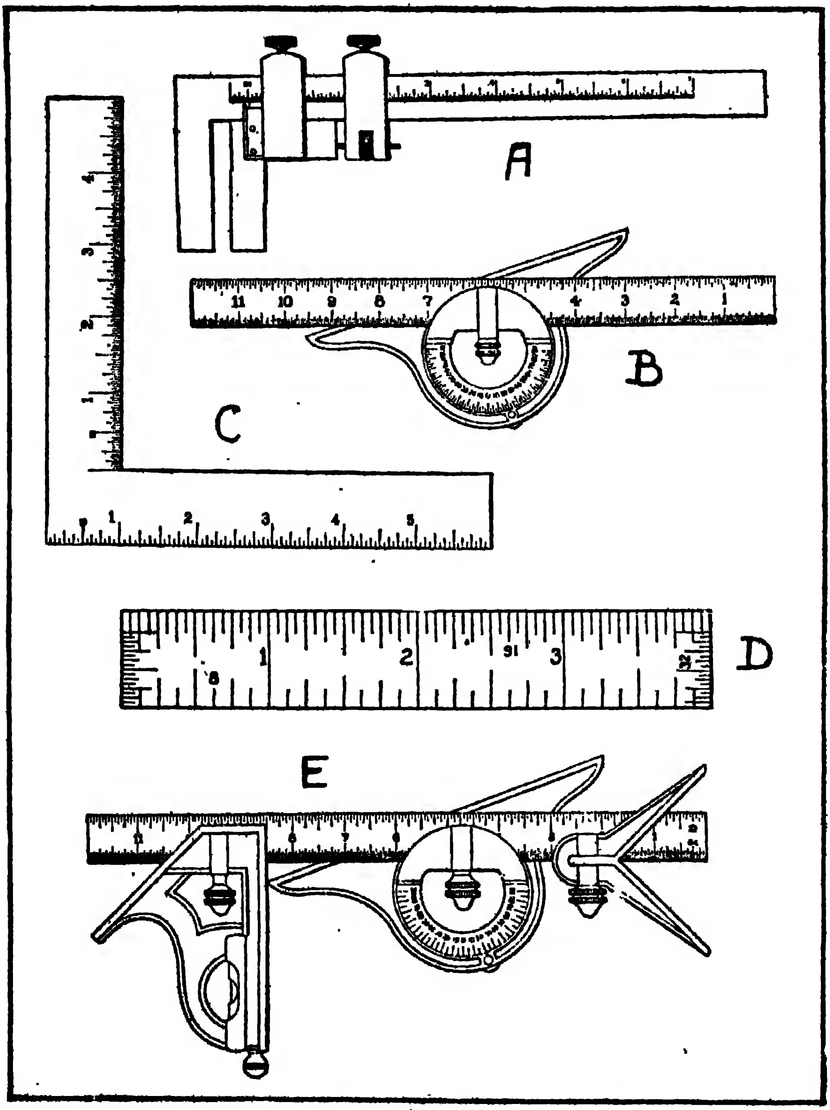


Fig. 71.—Measuring Appliances for the Machinist and Floor Man.

be about an eighth of an inch thick on the twelve-inch size, which is that commonly used with combination squares, protractors and other tools of that nature. The repairman's scale should be graduated both with the English system, in which the inches are divided into eighths, sixteenths, thirty-secondths and sixty-fourths, and also in the metric system, divided into millimeters and centimeters. Some machinists use scales graduated in tenths, twentieths, fiftieths and hundredths. This is not as good a system of graduation as the more conventional one first described.

Some steel scales are provided with a slot or groove cut the entire length on one side and about the center of the scales. This permits the attachment of various fittings such as the protractor head, which enables the machinist to measure angles, shown at Fig. 70, B, or in addition the heads convert the scale into a square or a tool permitting the accurate bisecting of pieces of circular section. Two scales are sometimes joined together to form a right angle, such as shown at Fig. 70, C. This is known as a square and is very valuable in ascertaining the truth of vertical pieces that are supposed to form a right angle with a base piece. The Vernier is a device for reading finer divisions on a scale than those into which the scale is divided. Sixty-fourths of an inch are about the finest division that can be read accurately with the naked eye. When fine work is necessary a Vernier is employed. This consists essentially of two rules so graduated that the true scale has each inch divided into ten equal parts, the upper or Vernier portion has ten divisions occupying the same space as nine of the divisions of the true scale. It is evident, therefore, that one of the divisions of the Vernier is equal to nine-tenths of one of those on the true scale. If the Vernier scale is moved to the right so that the graduations marked "1" shall coincide, it will have moved one-tenth of a division on the scale or one-hundredth of an inch. When the graduations numbered 5 coincide the Vernier will have moved five-hundredths of an inch; when the lines marked 0 and 10 coincide, the Vernier will have moved nine-hundredths of an inch, and when 10 on the Vernier comes opposite 10 on the scales, the upper rule will have moved ten-hundredths of an inch, or the whole of one division on the scale. By this means the scale,

though it may be graduated only to tenths of an inch, may be accurately set at points with positions expressed in hundredths of an inch. When graduated to read in thousandths, the true scale is divided into fifty parts and the Vernier into twenty parts. Each division of the Vernier is therefore equal to nineteen-twentieths of one of the true scale. If the Vernier be moved so the lines of

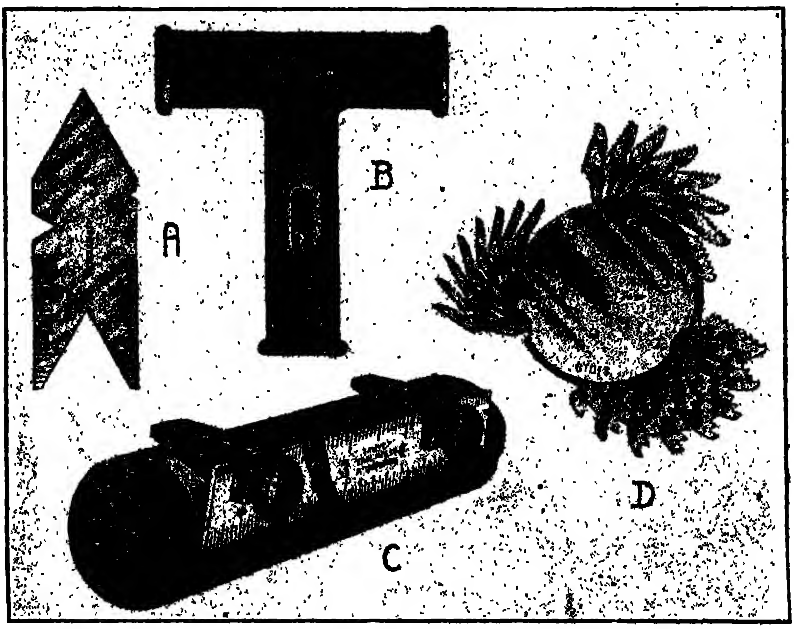


Fig. 72.—Measuring Appliances of Value in Automobile Repair Work.

the first division coincide, it will have moved one-twentieth of one-fiftieth, or .001 inch. The Vernier principle can be readily grasped by studying the section of the Vernier scale and true scale shown at Fig. 73, A.

The caliper scale which is shown at Fig. 71, A, permits of taking the over-all dimension of any parts that will go between the jaws. This scale can be adjusted very accurately by means of fine thread screw attached to movable jaw and the divisions may be divided by eye into two parts if one sixty-fourth is the

smallest of the divisions. A line is indicated on the movable jaw and coincides with the graduations on the scale. As will be apparent, if the line does not coincide exactly with one of the graduations it will be at some point between the lines and the true measurement may be approximated without trouble.

A group of various other measuring tools of value to the machinist is shown at Fig. 72. The small scale at A is termed a "center gauge," because it can be used to test the truth of the taper of either a male or female lathe center. The two smaller

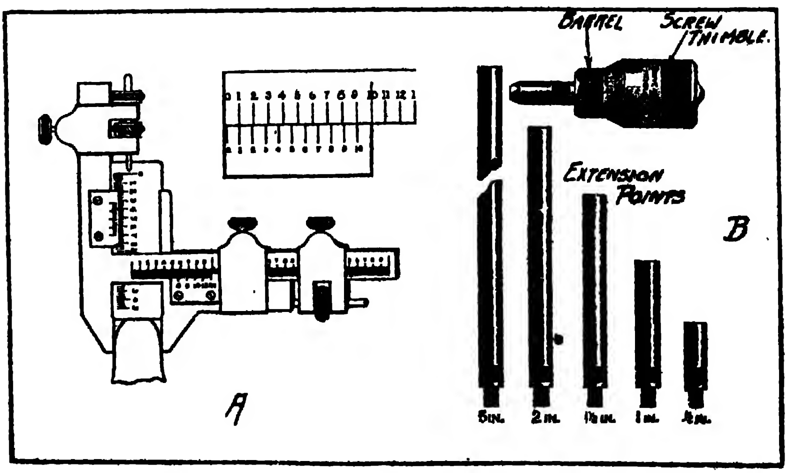


Fig. 73.—At Left, Special Form of Vernier Caliper for Measuring Gear Teeth; at Right, Micrometer for Accurate Internal Measurements.

nicks or v's indicate the shape of a standard thread, and may be used as a guide for grinding the point of a thread-cutting tool. The cross level which is shown at B is of marked utility in erecting, as it will indicate absolutely if the piece it is used to test is level. It will indicate if the piece is level along its width as well as its length.

A very simple attachment for use with a scale that enables the machinist to scribe lines along the length of a cylindrical piece is shown at Fig. 72, C. These are merely small wedge-shaped clamps

having an angular face to rest upon the ears. The thread pitch gauge which is shown at Fig. 72, D, is an excellent pocket tool for the garage mechanic, as it is often necessary to determine without loss of time the pitch of the thread on a bolt or in a nut. This consists of a number of leaves having serrations on one edge corresponding to the standard thread it is to be used in measuring. The tool shown gives all pitches up to 48 threads per inch. The leaves may be folded in out of the way when not in use, and their shape admits of their being used in any position without the remainder of the set interfering with the one in use. The fine pitch gauges have slim, tapering leaves of the correct shape to be used in finding the pitch of small nuts. As the tool is round when the leaves are folded back out of the way, it is an excellent pocket tool, as there are no sharp corners to wear out the pocket. Practical application of a Vernier having measuring heads of special form for measuring gear teeth is shown at Fig. 73, A. As the action of this tool has been previously explained, it will not be necessary to describe it further.

Where great accuracy is necessary in taking measurements the micrometer caliper; which in the simple form will measure easily .001 inch (one-thousandth part of an inch) and when fitted with a Vernier that will measure .0001 inch (one ten-thousandth part of an inch), is used. The micrometer may be of the caliper form for measuring outside diameters or it may be of the form shown at Fig. 73, B, for measuring internal diameters. The operation of both forms is identical except that the internal micrometer is placed inside of the bore to be measured while the external form is used just the same as a caliper. The form outlined will measure from one and one-half to six and a half inches as extension points are provided to increase the range of the instrument. The screw has a movement of one-half inch and a hardened anvil is placed in the end of the thimble in order to prevent undue wear at that point. The extension points or rods are accurately made in standard lengths and are screwed into the body of the instrument instead of being pushed in, this insuring firmness and accuracy. Two forms of micrometers for external measurements are shown at Fig. 74. The top one is graduated to read in thousandths

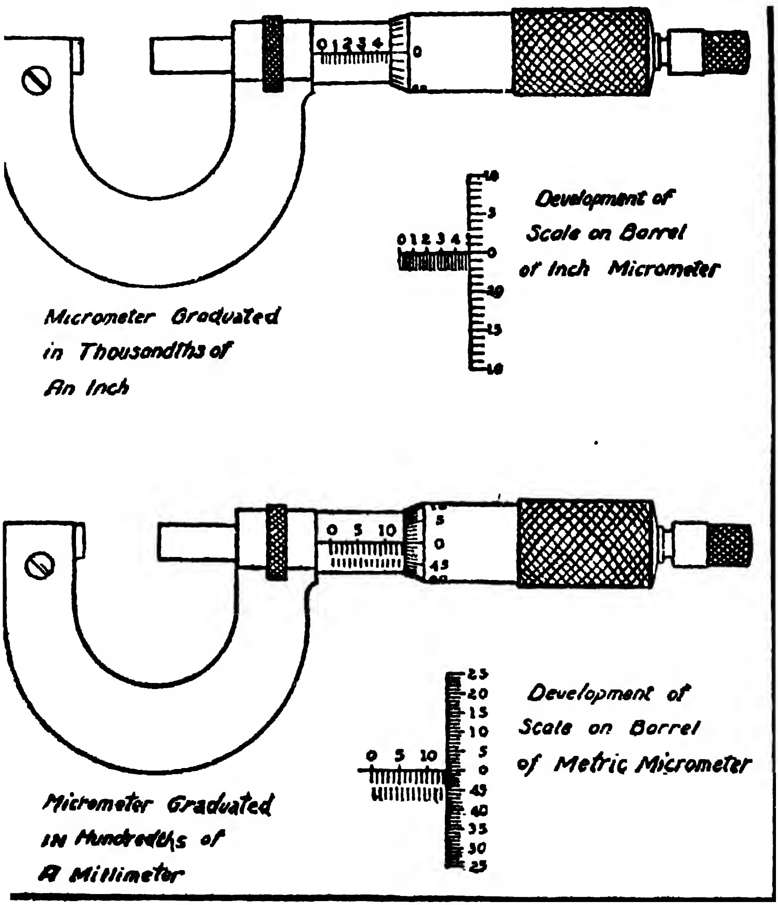


Fig. 74.—Standard Forms of Micrometer Caliper for External Measurements.

of an inch, while the lower one is graduated to indicate hundredths of a millimeter. The mechanical principle involved in the construction of a micrometer is that of a screw free to move in a fixed nut. An opening to receive the work to be measured is provided by the backward movement of the thimble which turns

the screw and the size of the opening is indicated by the graduations on the barrel.

The article to be measured is placed between the anvil and spindle, the frame being held stationary while the thimble is revolved by the thumb and finger. The pitch of the screw thread on the concealed part of the spindle is 40 to an inch. One complete revolution of the spindle, therefore, moves it longitudinally one-fortieth, or twenty-five thousandths of an inch. As will be evident from the development of the scale on the barrel of the inch micrometer, the sleeve is marked with forty lines to the inch. each of these lines indicating twenty-five thousandths. The thimble has a beveled edge which is graduated into twenty-five parts. When the instrument is closed the graduation on the beveled edge of the thimble marked 0 should correspond to the 0 line on the barrel. If the micrometer is rotated one full turn the opening between the spindle and anvil will be .025 inch. If the thimble is turned only one graduation, or one twenty-fifth of a revolution, the opening between the spindle and anvil will be increased only by .001 inch (one-thousandth of an inch).

As many of the dimensions of the automobile parts, especially of those of foreign manufacture or such parts as ball and roller bearings, are based on the metric system, the automobile repairman should possess both inch and metric micrometers in order to avoid continual reference to a table of metric equivalents. With a metric micrometer there are fifty graduations on the barrel, these representing .01 of a millimeter or approximately .0004 inch. One full turn of the barrel means an increase of half millimeter, or .50 mm. (fifty one-hundredths). As it takes two turns to augment the space between the anvil and the stem by increments of one millimeter, it will be evident that it would not be difficult to divide the spaces on the metric micrometer thimble in halves by the eye, and thus the average workman can measure to .0002 inch plus or minus without difficulty. As set in the illustration, the metric micrometers show a space of 13.5 mm., or about one millimeter more than half an inch. The inch micrometer shown is set to five-tenths or five hundred one-thousandths or one-half inch. A little study of the foregoing matter will make it easy to under-

stand the action of either the inch or metric micrometer. A table of metric equivalents will be found in the back of the book to enable the workman to change inches to millimeters, and vice versa, without any trouble.

Both of the micrometers shown have a small knurled knob at the end of the barrel. This controls the ratchet stop, which is a device that permits a ratchet to slip by a pawl when more than a certain amount of pressure is applied, thereby preventing the measuring spindle from turning further and perhaps springing the instrument. A simple rule that can be easily memorized for reading the inch micrometer is to multiply the number of vertical divisions on the sleeve by 25 and add to that the number of divisions on the bevel of the thimble reading from the zero to the line which coincides with the horizontal line on the sleeve. For example: if there are ten divisions visible on the sleeve, multiply this number by 25, then add the number of divisions shown on the bevel of the thimble, which is 10. The micrometer is therefore opened 10 x 25 equals 250 plus 10 equals 260 thousandths.

Micrometers are made in many sizes, ranging from those having a maximum opening of one inch to special large forms that will measure forty or more inches. While it is not to be expected that the repairman will have use for the big sizes, if a caliper having a maximum opening of six inches is provided with a number of extension rods enabling one to measure smaller objects, practically all of the measuring needed in repairing automobile parts can be made accurately. Two or three smaller micrometers having a maximum range of two or three inches will also be found valuable, as most of the measurements will be made with these tools which will be much easier to handle than the larger sizes.

Lathe Accessories and Lathe Tools.—Mention has been previously made of the marked utility of the lathe and its many advantages which make it an indispensable article of repair shop equipment. When one purchases a lathe there are a number of accessories that are usually furnished with that tool without extra cost. These include a large face plate, having a capacity equal to the full swing of the lathe, a steady rest and a follow rest. A number of the most important lathe accessories are shown in illus-

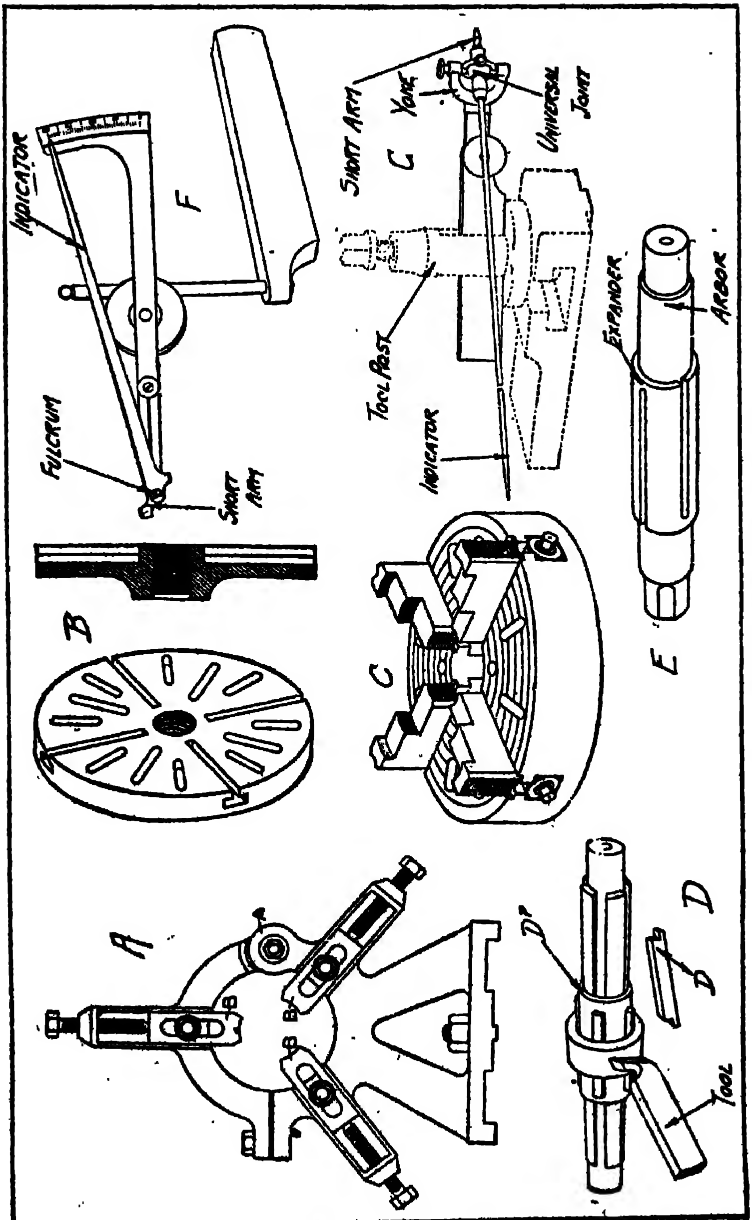


Fig. 75.—Special Fittings for Use with Lathe.

trations Figs. 75 and 76. The steady rest shown at Fig. 75, A, is used when a long shaft is being turned that cannot be supported by the tail stock center. This consists of a frame hinged at D, having three movable jaws, B, B, B. These jaws may be regulated by suitable screws and can be held firmly in place by setting down the clamping nut when they have been adjusted to form a suitable bearing for the piece to be turned. The usual construction of a face plate is shown at B. This can be made into a chuck by attaching face plate jaws such as are shown at Fig. 76, F. The face plate is provided with four T-slots to permit the easy insertion of clamping bolts, and also has numerous slots through the face to permit of bolting on angle plates or other fixtures to hold the work. A four-jaw chuck is shown at Fig. 75, C. This consists of a body fastened to a special face plate in a manner that insures concentricity with the spindle. Chucks may be of two types, universal chucks are those in which the four jaws may be controlled by any one of the screw heads while an independent chuck is a form having each jaw controlled by its individual screw independently of the other. Sometimes a chuck may be of a combination type, and the work-holding jaws may be operated universally or independently, as desired.

Mandrels or arbors to support work to be turned are shown at D and E. That at D is provided with slots adapted to take pieces of various heights, making it possible to use the common arbor as a basis for supporting work of various diameters by using the proper filling pieces. One of the filling pieces is shown at B 1, while the piece employed to hold the filling pieces in position in the mandrel slots is shown at B 2. The mandrel at E is an expanding form, in which a piece may be held tightly by moving the expander carrying the piece along the taper of the arbor until the piece is firmly held by the enlargement in size of the slotted expander sleeve.

The indicator shown at F, Fig. 75, is intended for centering work accurately in a chuck or on a face plate. This consists of a bell crank having considerable multiplication of leverage, so that a very slight movement of the short arm will mean about ten times as much of the long arm which serves as an indicator.

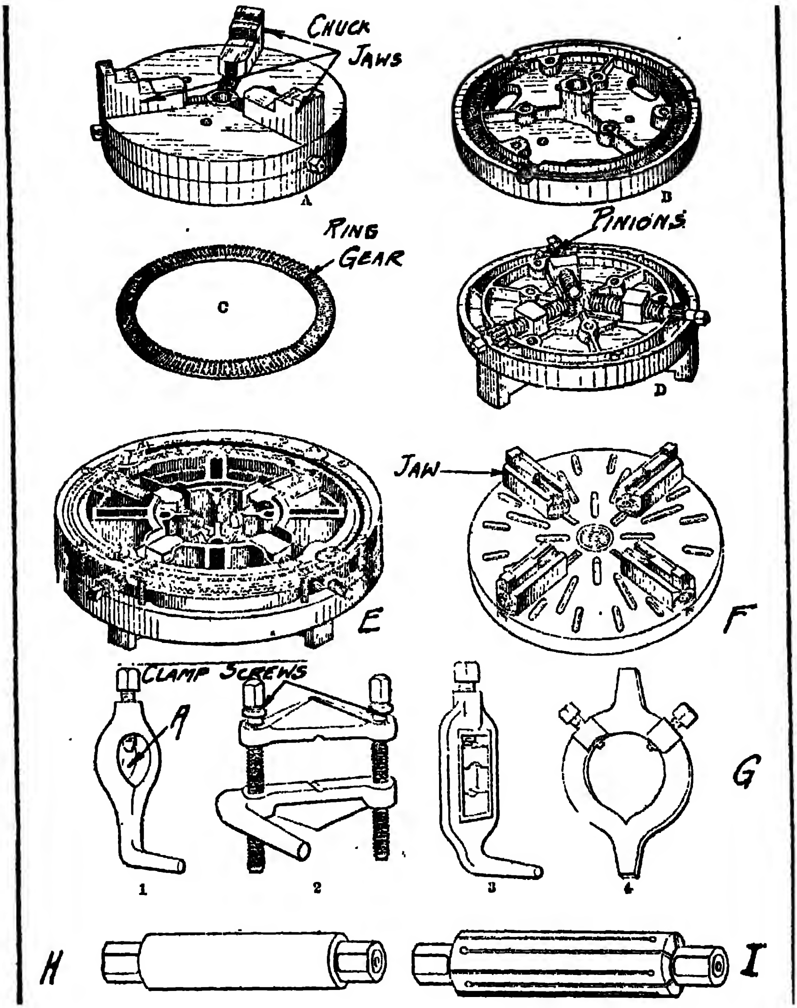


Fig. 76.—Outlining Construction of Lathe Chucks and Driving Dogs.

The indicator shown at G is also intended for use in the tool post, and is a gauge for indicating the truth of center holes. This also is a multiplying lever, fulcrumed in a universal joint, supported by a suitable yoke. The short arm of the indicator is

placed in the center, and if that runs out of truth it will greatly magnify the amount of running out which will be indicated by the degree of movement of the indicator point.

The internal construction of the usual pattern of three-jaw universal chuck is clearly outlined at B, C and D, Fig. 76. The view at A shows the chuck assembled. That at B shows the bottom half, which is attached to the head stock spindle. At C the bevel rack that is employed to cause the jaw-regulating screws to move in unison is shown. This bevel rack engages the bevel pinion shown on the adjusting screws at D. A movement of any one of the screws will therefore produce a corresponding and equal movement of the other two. At E the internal mechanism of a four-jaw chuck is shown. At F, a face plate fitted with chuck jaws is depicted. When work is supported on a mandrel it is necessary to provide some means of turning it, because the frictional contact on the live center (that carried by the head stock) is not sufficient to turn the arbor against the resistance of the cutting tool. Lathe dogs are used to turn the work, these being simple clamp members having projecting tails designed to engage one of the slots of the face plate. For round work the form shown at G 1, Fig. 76, is commonly used. The shaft or arbor to be driven is placed in the hole A, and firmly secured by tightening the clamp screw. For work other than round, the lathe dog shown at G 2 is very satisfactory. The lathe dogs at G 3 and 4 are special forms that can be used with either round or irregular work. The simplest form of arbor and that commonly used is shown at Fig. 76, H. This is a piece of steel ground to some standard size, but having a slight taper with the ends flattened to permit of secure holding by the lathe dog clamp screws. While the simple mandrel is a popular form, it has the disadvantage that the constant driving on and off of the work will produce depreciation and the mandrel will become reduced in size. Solid arbors are usually obtained in sets ground to standard diameters varying by thirty-seconds or sixteenths of an inch. It is conceivable that there would be many pieces to be handled that would not fit any standard solid arbor. In order to handle these odd size pieces an expanding support, either of the form shown at

Fig. 75, E, or 76, I, can be used. A mandrel of this kind is arranged so that the pieces designed to grip the work can be forced tightly against the piece to be turned by locating the expander farther on the taper, which is greater than that of the solid form.

No lathe is complete without a well-selected outfit of cutting

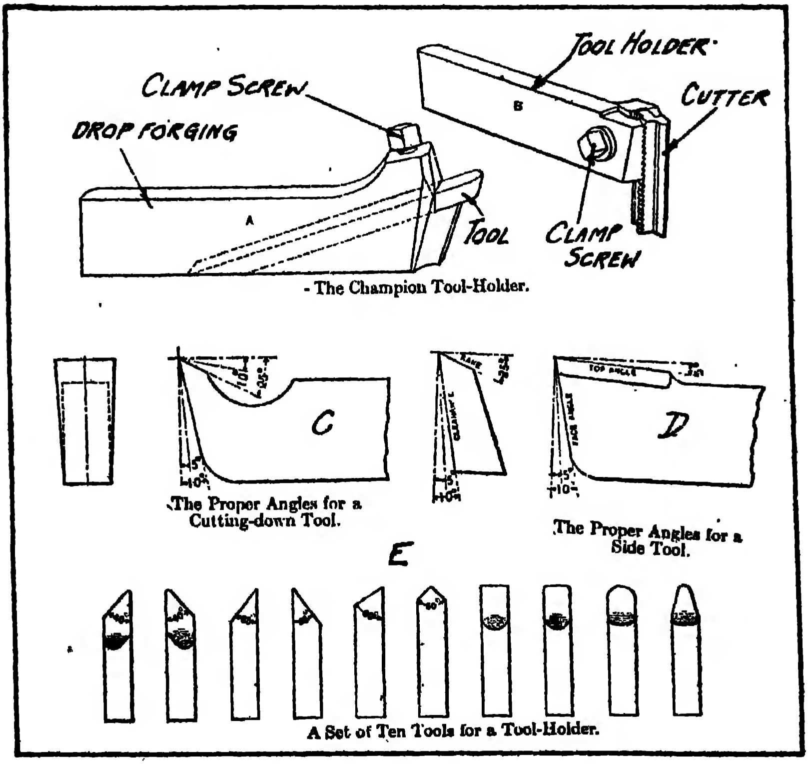


Fig. 77.—Lathe Tool Forms.

tools, which may be obtained in a great variety of forms. One of the most popular types for all around work is the "Champion" tool holder, which takes various cutting points, which can be readily changed in the master holder. This is shown at Fig. 77, A, with a simple round nose-turning tool in place. As will be ap-

parent, the tool which does the cutting is ground from a piece of square tool steel of proper size to fit the square hole in the body of the tool holder, which is usually a steel forging. Another form of "Champion" tool holder used for thread cutting is shown at B, Fig. 77. The cutter may be adjusted as it wears or is reduced in size by grinding by loosening the clamp screw and raising the cutting tool which is provided with a series of ratchet teeth, and then once again tightening the clamp screws which brings the ratchet teeth on the cutter and on the tool holder into positive engagement. The proper angles for a cutting-down tool are shown at C, and a side tool at D. The angle on the front edge of the tool is known as a clearance angle, while that from the cutting point back is known as the rake on a straight cutting-down tool. On the side tools there is another angle to be considered, known as the top angle. This is clearly indicated. The form of the cutting point used depends largely upon the characteristics of the material to be cut. The first consideration relates to the softness of the material, the other to structure, whether it is crystalline like cast iron or fibrous like wrought iron. The clearance is added to the tool to prevent it from rubbing on the work, while the degree of rake determines the cutting ability or sharpness of the cutting edge, and gives freedom for the chip to leave the work. A lathe tool should always be set so the cutting edge will be very nearly at a point that would correspond to a horizontal line drawn through the center of the work. If a tool is set too low, it will tend to dig into the work and force it from the centers, whereas if it is set too high, the angle of clearance will be reduced and the work will rub against the bottom of the tool. Many machinists favor setting the cutting edge just a little above the center or at a point corresponding to about five degrees above the horizontal line drawn through the axis.

A complete set of cutting tools for use with the Champion tool holder, shown at Fig. 77, A, is clearly outlined at Fig. 77, E. The tools are made of various grades of tool steel, which is a high carbon alloy capable of being hardened by raising its temperature to about 1500 degrees Fahr. and then quenching in water, oil or brine, according to the degree of hardness desired. Various alloy

steels containing tungsten, molybdenum, cobalt, and other substances are also obtainable, these possessing desirable qualities such as ability to keep their edge at greater heat than tool steel of the straight high carbon form, or of having greater resistance for cutting tough metals such as the chrome-nickel or chrome-vanadium steels so widely used in automobile construction.

The Armstrong tool holders are made in a variety of patterns,

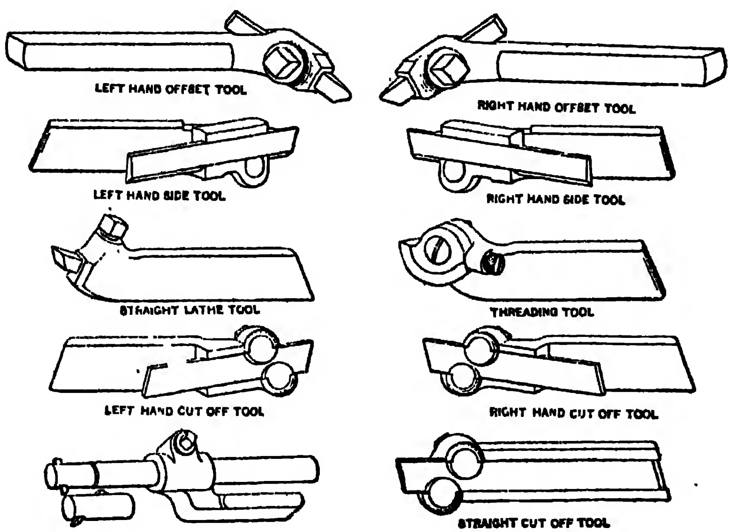


Fig. 78.—Armstrong Tool Holders for Many Uses.

the most common of which are shown at Fig. 78. As each is named in the illustration, further description is unnecessary. The general construction is the same for all tools, the main portion or body being a steel forging not subject to deterioration, while the cutting point or tool is readily removable for grinding or replacing. While the tool holder has many advantages, it is often necessary to make special lathe tools such as when turning filets, boring and other operations where the conventional form

of tool holder could not be used to advantage. Before the advent of the tool holder, lathe tools were forged of tool steel by the blacksmith according to the individual preferences of the machinist having the work done. While the forged tools are entirely satisfactory, it is not practical to use special cutting steel on ac-

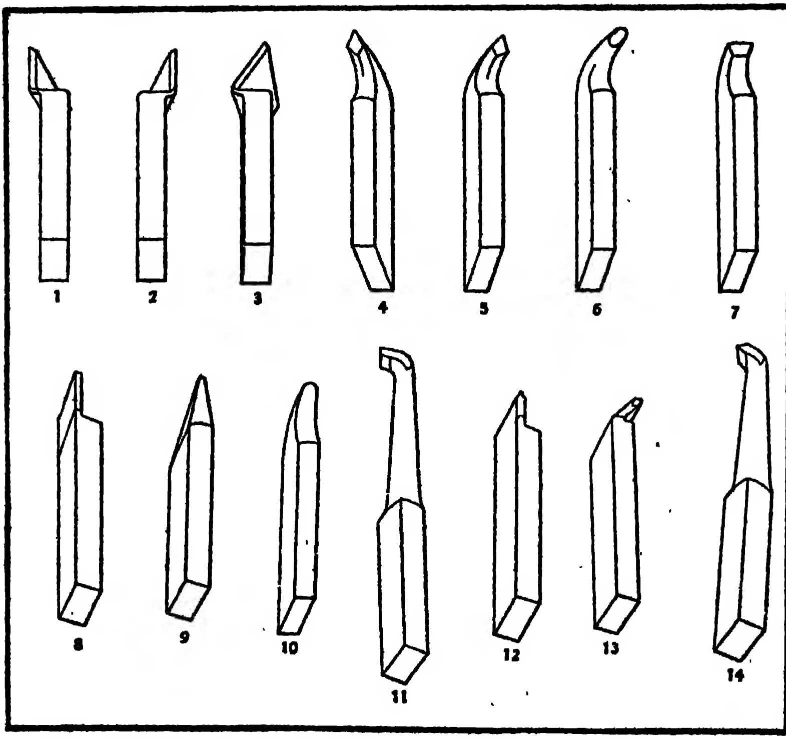


Fig. 79.—Set of Ordinary Hand Forged Cutting Tools for Use in Lathes.

count of the great cost of this material. As practically the only point where the high grade steel is desired is around the cutting edge, it will be apparent that it would be very wasteful to use that material for the body of the tool, which could be just as well made of a cheaper grade of steel. This, of course, is the great advantage of the Armstrong tool holder and similar devices. A

set of hand-forged tools ordinarily used in lathe work are shown at Fig. 79. That at 2 is a right-hand side tool, that at 1 is a left-hand side tool. The others in order are as follows: 3, right-hand bent; 4, diamond point; 5, right-hand diamond point; 6, round nose; 7, finishing tool for cast iron; 8, cutting off tool; 9, threading tool; 10, roughing tool; 11, tool for boring; 12, fine threading tool; 13, right-hand bent threading tool; 14, inside threading tool.

The lathe may be fitted with various attachments that will permit it to take the place of practically any other machine tool. Some of these have been previously illustrated. Many of the surfaces of automobile parts, especially of bearing points on shafts are finished by grinding and as a regular grinding machine is an expensive investment, owing to the fact that there would not be enough work to keep it busy; various forms of grinding attachments that can be placed directly on the lathe have been devised. Those outlined at Fig. 80, may be used for either external or internal grinding. The attachment for external grinding shown at B, and C, consists of a simple stand that may be attached to the tool post carriage and which supports a wheel carrying arbor and driving pulley. In order to permit the lathe carriage to be moved along the lathe bed, the attachments are driven by a long driving drum driven from the lathe countershaft and supported by an independent cross shaft of its own, above the lathe bed, and a little to one side of the lathe centre so the driving belt will not interfere with the work, which is usually supported by centers. The tool for internal grinding is practically the same as that for external work except that an extension arm is provided to carry the outboard bearings of the wheel spindle. These devices must be very rigid as in most internal work wheels of small diameter must be used, which, of course, must be turned at high speed in order to attain the recommended peripheral velocity of 5,000 to 6,000 feet per minute. The grinding attachment shown at D, is the form that can be used in boring cylinders and similar work, while that at C, would be used for external grinding on shafts and pins.

Miscellaneous Tools and Appliances.—The appliances shown at Fig. 81 are useful and should be included in the equipment of all

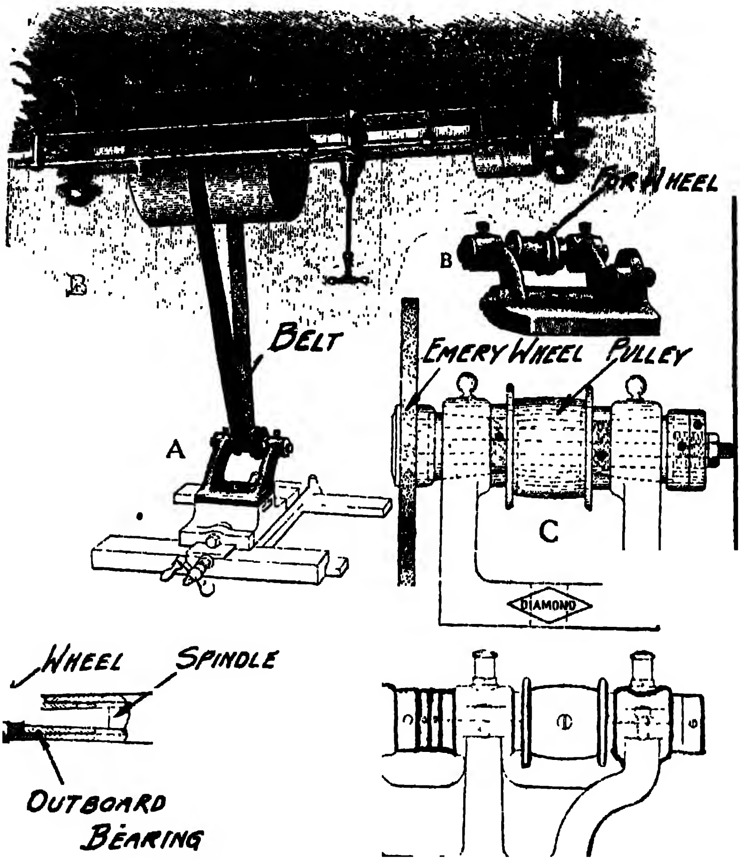


Fig. 80.—Grinding Attachments for Internal or External Work on Lathe.

shops where labor-saving tools are necessary to profitable conduct of business. At A, is depicted a simple machine for straightening bent stock, shafting, drills, reamers, drive shafts, axles, spindles, arbors, broaches and other similar components. It consists of a cast iron frame on which V-blocks slide, the work being supported by these, and a large screw by which pressure is exerted against the bent part to straighten it. A light steel bar is placed

in front of the centers for convenience of holding chalk or pencil when testing work that has been straightened, and adjustable centers are provided to support the shaft at the ends when testing for straightness. These are made in various sizes and are very useful in reclaiming tools, stock and shafting often thrown in the scrap heap and save time and money over the common method of hammering, centering work in lathe and testing. A moment's work may save a finished spindle or arbor that would be difficult to restore by use of hammer and anvil. This differs from the form previously described in that it has a substantial cast iron base to support it, also in other minor details.

The angle-bending tool at B, is a very powerful, but simple machine intended to be operated by hand for bending steel and iron rods or bars to various angles without heating. The machine shown is a combination type, it can be used for light or heavy stock, and will bend anything from light drill rod to one inch iron bars, or flat stock four inches wide by one-half inch thick or its equivalent. Light stock is bent by swinging the dies with the hand lever, heavier material is formed by using the ratchet lever and pinion to move the dies. This is devised to be set on the top of a strong post, which is set in the center of the floor of the shop so that any length of stock may be bent. Various dies are furnished and one can make U-fittings, hooks, screw-eyes and rings as well as angle pieces.

As the practise of using the softer alloys for bearings is common, a babbitt melter is a useful fixture to install in any repair shop doing considerable overhauling work. This consists of a large melting pot adapted to set on a bench, having a gas burner under it to heat the metal. One pipe is intended for gas, the other for an air blast from blower or foot bellows. This is a much cleaner method of melting bearing metal than the forge fire, the coal used often containing such elements as sulphur which may change the character of the alloy. It is also more convenient and quicker. A pot used for this purpose is shown at Fig. 81, C.

The soda kettle shown at D is used for removing grease and dirt from small tools, parts of automobiles, and machinery. A coil of steam pipe is used to heat the solution in which the articles

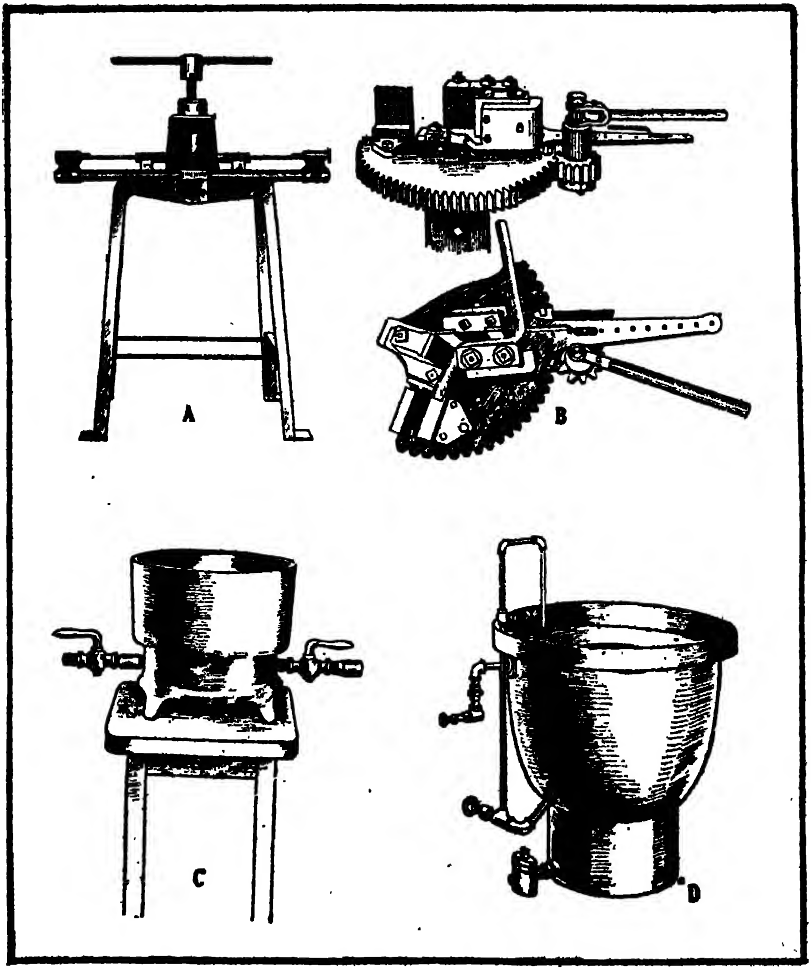


Fig. 81.—Useful Appliances to be Included in the Repair Shop Equipment.

are placed. This consists of washing soda and water, and pieces immersed in the solution dry without rusting when taken out. Such kettles usually have a capacity of 50 or 60 gallons and are intended to be placed in any convenient location among the machine tools. Others are of such form that they can be placed against a wall or in a corner. A removable wire basket or cage

for receiving the work is provided, and a small perforated bucket or shaker is furnished for washing small pieces. This method of cleaning parts is superior to the common method of using gasoline, as it reduces the fire risk appreciably and the soda solution cuts the grease fully as well as the inflammable hydrocarbon.

It is often possible to extemporize special tools that will serve the purpose quite well by making simple additions to ordinary tools that may have outlived their usefulness and no longer be suitable for the purpose for which they were primarily intended. Two useful attachments that can be easily fitted to the ordinary type of monkey wrench, when the jaws have become so sprung that they are no longer suitable for turning nuts, will permit these tools to be used on pipe. These are outlined at Fig. 82, A, B, and C. That at A, is a simple pipe cutter, comprising a jaw member having a recess to receive the jaw of the wrench, this being fitted with parallel arms adapted to straddle the wrench shank. A cutting wheel or disc is mounted in a block sliding in and guided by a suitable yoke piece. This block and the roll it carries can be moved as desired by turning the handle on the feeding screw. Simple clamp screws insure that the attachment will be easily and quickly attached to the wrench. The pipe is placed between the movable jaw of the wrench and roller, and is backed by the shank of the wrench, as indicated in the illustration. This device is used in the same manner as a pipe cutter, the wrench being revolved around the pipe and the pressure on the cutter block being increased gradually to cut deeper into the pipe each revolution.

The device shown at B is an extremely simple member, having a series of serrations or teeth to permit it to grip a round surface. This is made of hardened steel and has a simple clip member by which it may be easily attached to the fixed jaw of the wrench. The U-shape piece is adapted to closely engage the top and sides of the wrench jaw, the tooth plate is pivoted to the U-member in such a way that it will lie beneath the face of the fixed wrench jaw. A locking member, composed of a pin having a grooved end and retention spring, is passed through the U-member to hold the attachment in place. Either of the attachments shown at A, or B, may be fitted to a monkey wrench without impairing its usefulness

for the work for which it was primarily intended, as they are readily removable. The method of fixing a wrench so that it will serve as a tube or pipe cutter shown at C, means that some machine work is necessary, this consisting merely of boring a small hole through each jaw of the wrench. The hardened steel, beveled edged discs used in pipe cutters can be purchased for a

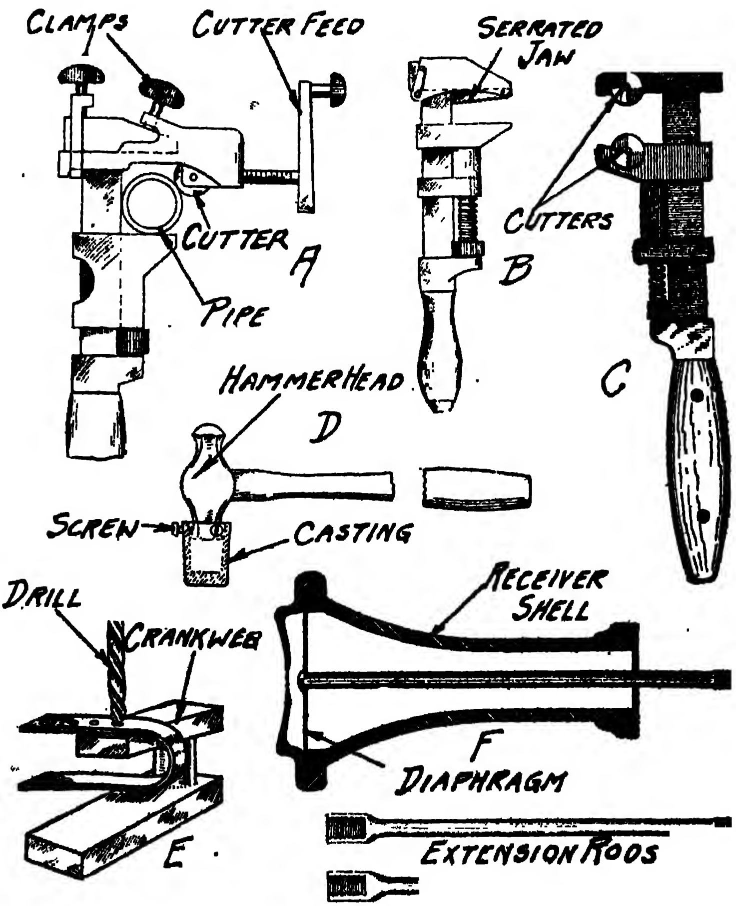


Fig. 82.—Showing Various Attachments for Use with Standard Tools.

small sum from any hardware store. The holes bored through the wrench jaws correspond to the size of that in the disc. A stove bolt passed through each disc acts as a bearing and is tightened down so the discs fit snugly against the jaws of the wrench, yet not tightly enough to prevent them from turning. Different sizes of pipe may be cut by simply adjusting the jaws as would be necessary to fit the wrench on various size nuts.

A soft metal hammer is very useful, but in some cases it may be used so seldom that the expense of buying a copper or babbitt hammer would not be warranted. A simple substitute is shown at Fig. 82, D. This is a copper, soft brass or babbitt casting fitted to the hammer head by three screws. The pattern for the casting can be easily made and can be turned out hollow, no core being necessary. If lead or babbitt metal is used, the casting should be somewhat heavier than if a stronger material, such as copper or brass is employed.

Some types of work, such as light U-shape brackets and similar members are not easily drilled on account of the difficulty in holding these on the drill press. At Fig. 82, E, a method of utilizing a section of a discarded crankshaft for making a drilling block is clearly shown. The cheeks of almost all crankshafts are planed smooth and parallel, thus making that portion of the shaft particularly suitable for this use. The journals are sawed off close to each web and these are filed or milled so that the cheek will rest firm and level on the drill press bed. The block shown may be used for drilling all light bent work and the raised portion enables the bent part of the work to clear during the operation of drilling. A block of this nature may be easily clamped onto the drill press table by a standard spring clip.

Modifications of the stethoscope employed by physicians are offered for detecting noisy operation of automobile engines, gear boxes and other portions of the mechanism. The operation of these devices, as is well known, is to localize the noise and thereby ascertain the part or parts at fault. A very good sonoscope, as these instruments are called, that may easily be contrived by the repairman is shown at Fig. 82, F. This is made from an old telephone receiver shell, the construction being so clear that further descrip-

tion seems unnecessary. The pieces shown below the receive are extensions by which the rod transmitting the sound to the diaphragm may be lengthened when necessary to reach inaccessible parts.

An adjustable socket wrench that has considerable merit is shown at Fig. 83, A. This consists of a main handle T, made of square section stock with a cross bar welded to the top by which it may be turned, a piece of spring steel bent as shown and a clip of rectangular form riveted to the lower end of the wrench handle. Owing to the tapering sides, as the handle is drawn up the jaws are permitted to open and the space between them increases, adapting the tool for a larger nut than when the handle was pushed way down and the jaws brought closer together.

Gaskets and washers of various material, such as rubber, asbesto or felt are widely used in automobile construction. These ar hard to cut by the ordinary method of using scissors or a knife A washer cutter, such as shown at Fig. 83, B, forms a useful articl of repair shop equipment. The cutting blade is carried by a sliding support which may be set at any desired point on the graduated cutter bar. The cutter bar is turned by a large T-handle which not only provides leverage to rotate the cutter but also screws the member carrying the cutter bar into the supporting arm and provides a feed so the cutting tool will go through the material of which the washer is to be made.

Mention has been previously made of the desirability of including a soft hammer in the repairman's kit and a simple fitting that can be attached to an ordinary machinist's hammer has been previously described. The "Horat" soft hammer mold which is shown at Fig. 83, C, makes it possible for the repairman to make his own soft hammers at relatively slight expense. The operation is extremely simple. A piece of pipe of the size that is to serve for the handle is inserted in the mold and the swinging top or upper portion of the mold is brought in place and tightly clamped again the pipe by a member provided for that purpose. Old babbitt metal or worn out bushings of white metal are placed in the ladle portion of the mold and are then melted over the forge fire. When the metal is fluid, the mold may be easily picked up and tilted to

allow the molten material to flow from the ladle into that portion of the mold surrounding the piece of pipe. When the metal has cooled, a mallet head of substantial proportions will be found cast around the pipe handle.

One of the most disagreeable of the operations incidental to repairing is fishing for lost bolts and nuts in the narrow confines of a motor crank case, gear case or in the small space between

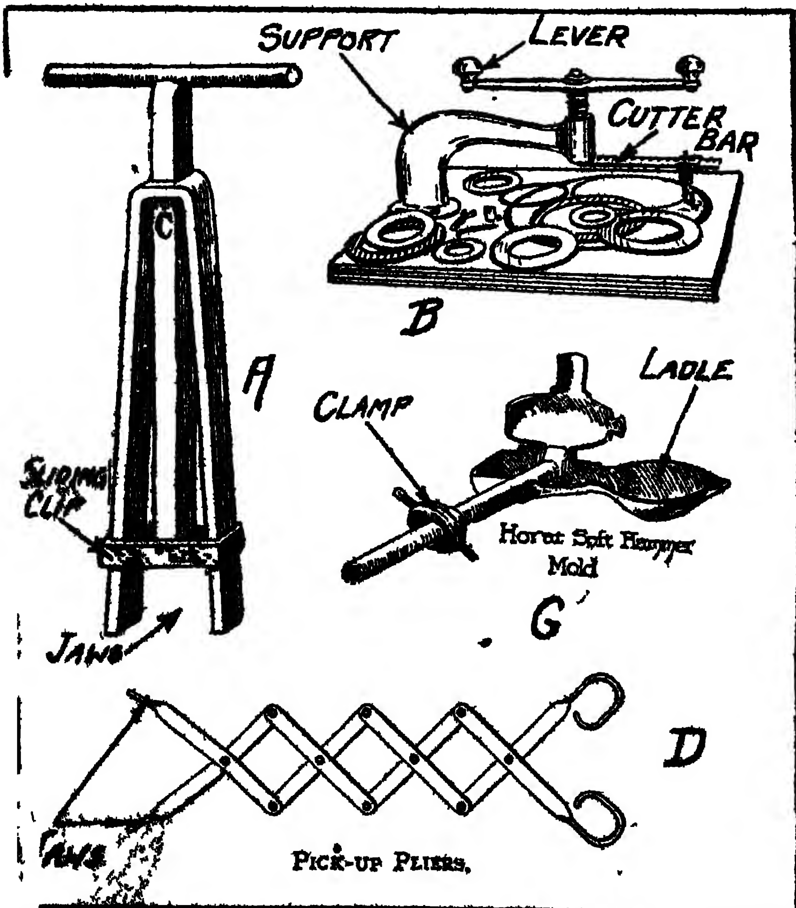


Fig. 83.—Miscellaneous Devices for the Repair Shop.

the engine and the under pan, where it is difficult to thrust the hand or arm. The usual implement for fishing out the lost articles is a bent wire or copper tube, but the pickup pliers built on the lazy tongs principle shown at Fig. 83, D, make it possible to catch almost any object. The pliers measure 21 inches in length, extended, but when folded they are but 7 inches long.

Special Home-made Tools.—The tool outfit of most automobile repairmen of experience includes many special tools that they have made from time to time for doing special jobs. Many of these are well adapted for general work and some that were made by the writer when he was in the repair business are shown at Figs. 84 and 85. While the method of construction is apparent from the sketches, it may be well to describe the uses to which the tools can be put. At Fig. 84, A, is shown a cotter pin tool used for extracting split pins, where these are employed as a locking means. It will be noted that a fin of metal is provided at the hooked end which serves as a point of support by which considerable leverage may be exerted by a simple rocking motion the fin being supported by any convenient projection adjacent to the pin to be removed. The other end of the tool is flattened and bent up to form a spreader to expand the ends of the pin after this member has been inserted in the bolt. The offset screw driver shown at B, is easily bent up from a heated piece of tool steel, filed to shape and then hardened and tempered. These may be made in various sizes depending on the size of the screws they are to remove.

At C, is shown a socket wrench having a T-handle that may be made to fit any odd size bolt head or nut that the regular stock sockets do not provide for. A bent box wrench which can be used for spark plugs is shown at D. A home-made universally jointed T-handle for turning sockets such as shown at F, is clearly outlined at E. At the present time these tools may be purchased fully as cheaply as they can be made, unless some odd size is needed that cannot be bought. The socket wrench shown at G, was made from an old bit stock and was intended to fit the clamping nuts on quick detachable demountable rims. Modifications of this tool will prove useful wherever there are a number of nuts of the same size that must be removed from time to time. The forged T-handle

screw driver shown at H, was made to handle large screws and slotted head bolts that could not be turned with the usual pattern of screw driver. The wrench at I was specially devised for removing castellated valve chamber caps. The bars at J, and K, are very useful for bending or straightening mud guard irons, step and lamp brackets, tierods, etc. That at J, is an adjustable type, one of the projections being movable and capable of being inserted in any one of the holes provided on the handle. At L, is shown

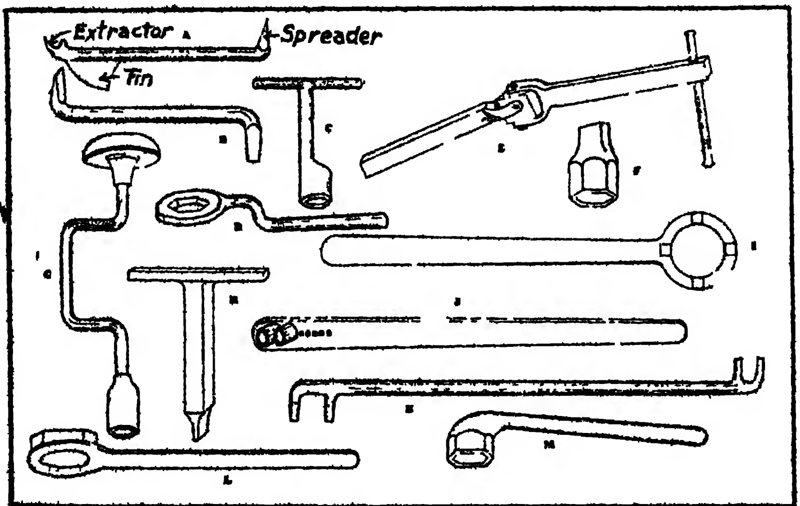


Fig. 84.—Special Tools That Simplify Automobile Repair Work.

a special wrench made for removing the valve chamber caps having an internal hexagon socket and also hub caps of the same design. The wrench at M, was made to handle cylinder head retaining bolts that could not be reached with an ordinary monkey wrench, because a wrench of the proper size was too large through the jaws to fit the bolt heads which were set in depressions in the cylinder head casting.

Another group of useful tools is shown at Fig. 85, these also being so clearly outlined that but brief description will be necessary The two blocks A, are used for flaring the ends of copper or

brass tubing used in making oil or fuel leads so they will fit the coned end of couplings or unions. The blocks are steel, cast iron or bronze, of the same size and held together in proper relation by small dowels. The holes are of proper size to handle 3-16, 1-4, 5-16, 3-8 and 7-16 inch diameter tubing respectively, and the ends are countersunk so the desired flare may be obtained. In using these, the tube is placed in the proper sized hole, and firmly grasped

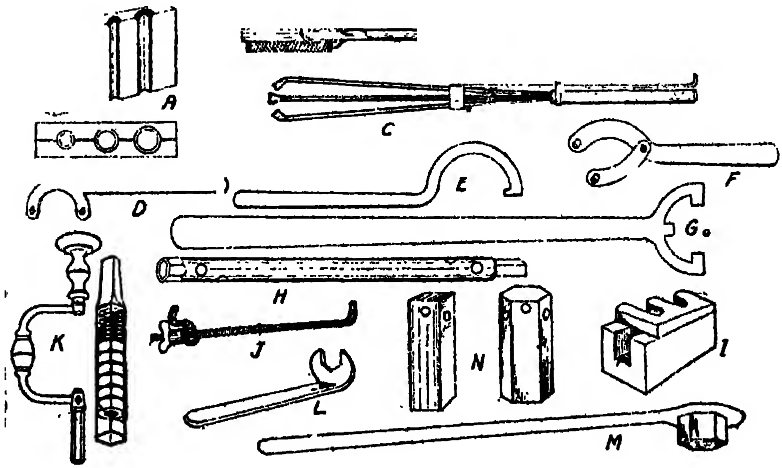


Fig. 85.—Another Group of Special Tools and Appliances of Value to Automobile Repairmen.

between the blocks in a vise. A portion of the tube protrudes above the surface, and is expanded by driving a taper punch so the tubing fits the sides of the countersink.

There is no more annoying condition that confronts the repairman occasionally than dropping a bolt, nut or other small part into some particularly inaccessible place such as a crankcase or gearcase interior from which it must be removed at any cost. For this reason, the utensils illustrated at Fig. 85, are of special interest. That shown at B, is a small electro-magnet having a flexible handle so it can be thrust into very inaccessible places. The magnet

is a piece of soft iron about ½-inch diameter, having a hole bored at one end to receive a piece of ¼-inch annealed copper tubing.

Three layers of No. 18 magnet wire are wound around it, one end of the wire being soldered to the copper handle close to the point of juncture with the iron piece. The other end of the wire is brought through the tube and is allowed to protrude for several inches at the other end. A small terminal is soldered to the handle where the wire comes out. To use this, the magnet is connected to a six volt battery, preferably dry cells (as the resistance of the magnet winding is so low it might short circuit a storage battery), and brought in contact with the nut or bolt to be removed. If this is iron or steel, it will be attracted by the magnetic force and held to the magnet and it can be easily withdrawn.

Unfortunately, all small parts are not of magnetic material, and as such a magnet would not be of any use if the object were brass, copper or aluminum, the tool shown at B is also useful. This is made on the principle of a fruit picker, a number of fingers being bound together at one end and secured in a handle, while a sliding ring can be brought down toward the lower end to close them upon the object to be removed. The fingers are light steel rod, flattened and serrated at the lower end to afford a grip on an irregularly shaped piece. The sliding ring is worked by a light rod extending to the top of the handle where it may be easily raised and depressed when the lower portion is thrust in the interior of a crankcase, or gear housing in search of some matter out of place. Either of these devices will be found to have many uses, and the expense of making them is so slight as to be almost negligible.

It is not always possible to provide retention or clamping nuts having square sides to hold a wrench. In some cases this construction would be objectionable on account of appearance, in others, as in internal clamping nuts, it is not possible to fit either a hex or a square. Nuts of this form are usually provided with a series of holes drilled in their face, if of the internal form or with slots milled across their periphery, if of the external form. While it is possible to move these with a drift pin and hammer it is always preferable to use spanner wrenches for the purpose. These

are very simple and may be easily made by any repairman. The solid form shown at D, Fig. 85, has a disadvantage of only fitting one size of nuts. The adjustable form shown at F, which has a swinging arm, may be set to handle quite a range of work. The nut is turned by small pins projecting from the face of the wrench and adapted to fit into the holes in the nuts. For external nuts having milled slots, the wrench shown at Fig. 85, E, is used. The large spanner wrench shown at G, is utilized for removing valve chamber caps provided with a castellated top. The special socket wrench is useful where bolts or nuts must be turned from a distance as in working down through a seat or floor board where an ordinary wrench could not be handled

A chain repair block is shown at I. This consists of a cast iron base, having a channel milled through it or cored therein to fit the size of chain the block is to support. A piece of steel boiler plate, a little less in thickness than the chain roll diameter and having three projecting fingers is made to rest on the top of the block. The function of the slots between the fingers is to provide space for supporting the rollers while the chain link sides rest on the finger. This forms a secure method of holding the drive chain for driving out rivets that hold the chain links and rolls together. It is often difficult to replace a chain on sprockets if no tool is available for holding the chain ends together while inserting the master link. The simple tool shown at J, was made by the writer in less than a quarter of an hour and proved very useful for doing this work. The main portion consisted of a piece of cold rolled steel rod having a hook bent up at one end and carrying a wing nut and sliding hook on the other. The sliding hook was simply an eye piece having a hook formed at one end. Tightening on the wing nut moved the eye piece on the shank and the ends of the chain were brought together owing to the movement of the hooks which filled the space between two of the rollers at each end.

A magazine wrench which is useful in removing a number of nuts of the same size rapidly without necessitating handling them is shown at K. Tools of this form have been used by racing drivers

The device consists of a cheap bit brace and special long socket

wrench. A simple clip is attached to the socket wrench, this having a projecting pin into the interior in order to hold the nuts from coming out of their own weight or by spring pressure. A coil spring is used back of the nuts in order to force these down against the stop pin. Assume that a rim is held by six nuts. It will be apparent that all of the nuts may be carried in the body of the wrench without any trouble. To release the nut it is merely neces-

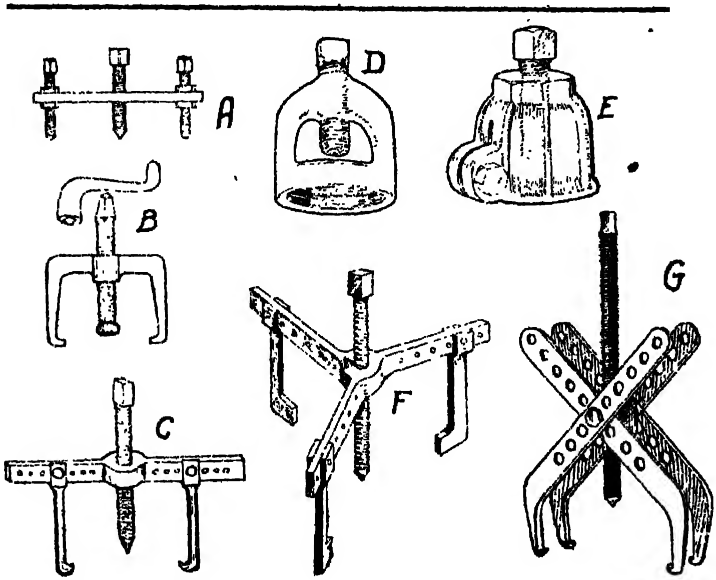


Fig. 86.—Showing Construction of Wheel and Gear Pullers.

sary to catch it on the thread, screw it home and then pull out the socket. The little lock spring will move back and permit another nut to drop in place ready to be screwed onto the next retaining bolt, the spring insuring constant feed. The special wrench shown at L, is the usual form of end wrench with the jaw portion bent at right angles to the handle. A wrench of this form can often be used where the regular type would be at a disadvantage. Mention has been previously made of valve chamber caps that were

provided with internal hexagon or square sockets. The wrench shown at M consists of a forged handle having a piece of bar stock of the proper section securely welded to it. The length of the handle provides considerable leverage, makes it possible to remove the valve caps even if these are rusted in place. The short pieces of bar stock shown at M are used for the same purpose, but are intended to be turned by a large monkey wrench or by inserting a lever or pinch bar in the holes provided for the purpose at the top of the bar.

Wheel and Gear Pullers.—When wheels or gears have seized on their axles, due either to want of lubrication or to grit, rust, etc., special forms of pullers are needed to remove them without injury. The form shown at Fig. 86, A, is intended to be used on gears that have threaded holes in the web to receive the screws on the end of the cross bar. When these screws are properly entered, pressure on the central screw will draw off the gear from the shaft. The form shown at B, is intended to be passed around the gear or pulley to be removed, as it has arms with hooked ends to obtain a purchase on the rim of the gear. The central screw is turned by a crank, but in other respects its action is similar to that shown at A. A simple form of wheel puller that may be made by any repairman is shown at Fig. 86, C. The crossbar is forged from a piece of scrap steel and provided with a series of holes equally spaced each side of the boss. This is drilled and tapped to receive a standard 1.125 inch screw pointed at its lower end to fit into the center hole left in the end of all axles or shafts that are finished by turning. The arms are forgings and can be moved back and forth as desired on the puller beam. The upper end of the puller arms are provided with yokes of sufficient size to permit the beam to drop in and are held in place by a through pin which can be easily removed to permit the arm to be changed from one hole to another according to the size of the object to be removed.

The large wheel puller shown at F, is practically the same in construction as that shown at C, except that it is more powerful and has three arms instead of two. The advantage gained by this construction is that the pressure is exerted at three equidistant points and it is not possible for the puller to spring sideways when

the pressure is applied to the screw as sometimes occurs with the two-armed form. The beam is a heavy steel forging, the arms of which are drilled with a number of holes so the hook members can be moved to accommodate various sizes of work. For removing wheels from live axle shafts, as is necessary on all non-floating rear axles, the devices shown at D and E are useful. These are practically heavier duplicates of hub caps provided with a pressure screw in the center forced in against the axle after the device is screwed on the wheel hub. The body castings may be of steel or bronze and even malleable or cast iron may be employed. The puller shown at E, has a minor advantage in that threads may be brought closer to the wheel hub by screwing the clamping bolt which tightens the body portion around the thread should that member be a trifle undersized.

The wheel puller shown at G, Fig. 86, is a new pattern capable of handling a wide range of work. The arms are heat-treated steel drop forgings and can be quickly adjusted to handle work as wide as thirteen inches. For small pieces such as pinions, cams, etc., of 2½ inches diameter or less, extension arms are provided to enable one to exert pressure for the removal of the small piece. The center screw passes through a threaded block into which the bolts holding the arms in place screw. As each arm is provided with nine holes and as they are capable of swinging on the fulcrum end it will be evident that a large variety of work can be handled with one wheel puller.

Typical Special Tool Equipment.—The makers of all the popular cars, especially those that are produced in any quantity, furnish special tools for the use of their repairmen or for those employed in the service stations of the agents. As an example of the special tools that it is possible to obtain, the assortment used by repairmen of Ford Model T cars is shown at Fig. 87. The device at A is a wheel puller designed to go on the hub in place of the hub cap. In operation it is the same as the form shown at Fig. 86, D and E. The tools shown at Fig. 87, B, C, D, F, G, and D-2, form part of the regular tool equipment. The box wrench at E is also furnished with each car and is a hub cap wrench having one end formed to fit the slabbed portion of the front wheel bearing

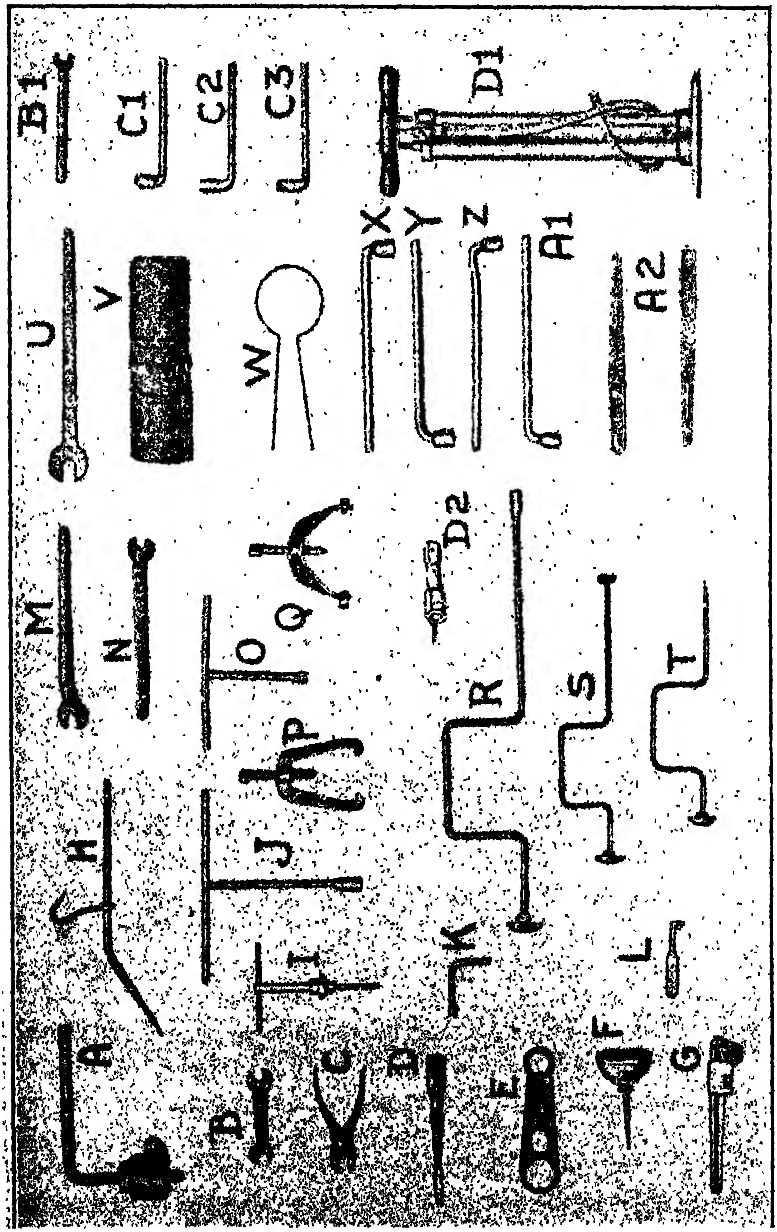


Fig. 87.—Special Tools of Value in Repairing Ford Automobiles.

adjusting cone lock nut. A valve spring lifter is shown at H, while a valve seat reamer is shown at I. The valves are turned while grinding by the special brace S, which can be used on all of the valves except the one on the rear cylinder, which is immediately under the dash board. To turn this valve the special wrench shown at L, is provided. A special T-handle socket wrench for handling ⅝-inch nuts or bolt heads such as used on the rear construction and various other points is shown at J. A T-handle screw-driver, for the set screws which are employed in retaining the camshaft bearings, is shown at O. The puller shown at E is for removing the cam gear from the camshaft, while that at Q is a transmission clutch puller. The brace shown at R, is a special socket wrench for ⅜-inch bolt nuts. The brace shown at T, is employed for removing the magnet-retaining screws in the magneto assembly. The tire irons at A-2, the tool roll at B, the pump at D-1. and the spark plug socket wrench at D-2 are all parts of the regular tool equipment furnished with each car.

The simple fitting shown at W, is a piston ring compressor employed to compress the rings in the piston grooves to facilitate easy assembly in the cylinder block. A number of special socket wrenches are shown at X, Y, Z; A-1, C-1, C-2 and C-3. These are all intended for use on the various fastenings used in holding the parts together. For example, that at X is a socket wrench for the crankshaft main bearing bolt nuts. That at Y is for ⅜-inch bolt heads or nuts. The wrench at Z is for removing the cylinder head retaining bolts. The wrench for removing the pinion drive shaft housing retaining stud nuts is shown at C-1, this being used for ⅜-inch nuts. The rear axle housing bolt nut wrench is shown at C-2, while the form outlined at C-3 is similar to that shown at C-1 except that it fits 11/32-inch nuts. The special end wrench at M, is for the flywheel retention cap screws, that at U, is for removing the large cam gear lock nut while that at B-1 is a regular open end wrench for ⅜-inch nuts. The prices on these tools are so low that it is cheaper to purchase from the factory than to attempt to make them.

Tools and Supplies Itemized.—The following lists are presented as a guide for the novice repairman or motorist who wishes to make

his own repairs and enumerate the most important of the tools necessary in automobile repairing and the supplies most generally used in restoring defective mechanism. It is not possible to enumerate all tools that can be used to advantage as their number is legion. However, selections of those needed can be made from the lists for the regular tool equipment and can be augmented as conditions dictate. The wider the range of work the shop is to attempt, the more complete the tool and supply stock must be.

TOOLS FOR THE REPAIR SHOP.

HAMMERS:

Blacksmith's hammer—4½ lb. head.
Blacksmith's sledge—10 lb. head, short handle.
Blacksmith's sledge—20 lb. head, long handle.
Machinist's ball pein hammers—1 lb. head, 2 lb. head.
Machinist's ball pein hammers—½ lb. head.
Machinist's straight pein hammers—4 oz. head.
Wooden or Rawhide Mallet.
Lead or Babbitt hammer.

WRENCHES:

Ratchet Handle Socket Wrench Set.
Six-inch Stillson wrench.
Twelve-inch Stillson wrench.
Eighteen-inch Stillson wrench.
Six-inch Coes or other monkey wrench.
Twelve-inch Coes or other monkey wrench.
Eighteen-inch Coes or other monkey wrench.
Set of double end S wrenches.
Assorted Spanner wrenches.
Bicycle wrench, small 4 inches.
Narrow jaw monkey wrench, 8 inches.
Bemis and Call Adjustable end wrench, 6 inches.
Bemis and Call Adjustable end wrench, 8 inches.
Spark plug socket wrench.
Small hand vise.

PLIERS, ETC.:

Combination pliers, 6 inches, 10 inches.
Side cutting, parallel jaw pliers.

PLIERS, ETC.—*Continued:*

Special anti-skid chain pliers.
Tire casing cut repair pliers.
Cotter pin-pliers.
Piston ring expanding pliers.
Tinner's snips.
Heavy shears.
Bolt cutter.

SCREW DRIVERS:

Jeweler's small screw driver.
Six inch screw driver, ¼-inch width blade.
Ten-inch screw driver, ⅜-inch width blade.
Twelve-inch screw driver, ½-inch blade.
T handle "Bulldog" screw driver.

MISCELLANEOUS TOOLS:

Wheel pullers, valve spring lifters, etc.
Breast drill, two-speed.
Valve seat reamers, valve head truing cutters.
Hand drill, one-speed.
Belt punch.
Bit brace, ratchet and bits.
Carpenter's cross cut saw.
Hacksaw frame and extra saws for tubing and bar stock.
Ratchet drill set.
Gasoline blow torch.
Spring winder, chassis spring spreader.
Scrapers (carbon).
Scrapers (bearing).
Jack plane and wood chisels.
Set of number drills.
Wire scratch brush, putty knife.
Set of taps and dies—S. A. E. standard.
Set of taps and dies—metric standards (foreign).
Set of taps and dies—American standard.
Soldering irons—large, medium and small.
Set of straight and taper hand reamers.

FILES, ETC.:

Twelve-inch bastard cut, flat.
Twelve-inch bastard cut, half round.

FILES, ETC.—*Continued:*

Ten-inch bastard cut, round.
Ten-inch bastard cut, square.
Ten-inch bastard cut, three-cornered.
Eight-inch second cut, flat.
Eight-inch second cut, half round.
Eight-inch finishing cut, flat.
Eight-inch finishing cut, half round.
Eight-inch finishing cut, rat tail.
Eight-inch finishing cut, three-cornered.
Six-inch finishing cut, flat.
Six-inch finishing cut, rat tail.
Set of file handles and file brush.
Small and large oil stones.

CHISELS, ETC.:

Cape chisels—small, medium and large.
Chipping chisels—small, medium and large.
Round nose chisels—small, medium and large.
Diamond point chisels—small, medium and large.
Center punches—small, medium and large.
Drift pins—1/16, 1/8, 3/16, 1/4, 5/16, 3/8, 1/2, 5/8 and 3/4-inch point.
Cotter pin puller.
Set of straight and offset scribers.

MEASURING TOOLS:

Carpenter's and machinist's tri-squares—small six-inch, large twenty-four inch.
Machinist's twelve-inch flexible scale, six-inch scale, 2-inch scale.
Carpenter's two-foot folding rule.
Caliper rule.
Combination square and protractor, 18-inch scale.
Spirit level, cross level.
External micrometers, one, two, three and 6-inch with extension pieces.
Internal micrometer, with extension pieces.
Thread gauge.
Hermaphrodite calipers—small, medium and large.
Small internal calipers.
Large internal calipers.
Small external calipers.
Large external calipers.
Spring dividers, small and medium.
Friction joint dividers, large.

BENCH EQUIPMENT:

Medium size pipe vise.
Large swivel vise.
Medium swivel vise.
Surface plate.
Small bench anvil.
Machinist's clamps.
C clamps—large, medium and small.
Straight edge and surface gauge.
Pyrene fire extinguisher.
Angle bender.

ELECTRICAL EQUIPMENT

Extension lamps with wood handle and steel cage.
Electric breast drill.
Storage battery charging means; Rheostat, lamps or rectifier.
Still for making pure water.
Voltmeter for testing storage batteries.
Ammeter for testing dry cells.
Hydrometers and hydrometer syringes.
Acid bottles and electrolyte crocks.
Extra strap connections, wing nuts and lead bolts.
Torch for lead burning.

TIRE REPAIR MATERIAL

Vulcanizer for casings.
Molds for same.
Vulcanizer for tubes.
Acid cure or cold vulcanizing set.
Stock outfit for vulcanizing and patching, rubber, canvas, etc.
Rubber cements, cut fillers, etc.
Air-compressor outfit.
Jacks, two of each size, large, medium.
Tire irons, special rim tools.
Valve tools, air pressure gauge.
Extra valves and valve parts.
Casing air bags or coil springs for use when vulcanizing.
Inner tube patches, inside and outside casing blowout sleeves.

REPAIR SHOP FURNITURE

Movable and wall benches.
Wheeled trucks, special jacks, trestles, etc.
Oil separator and filter.
Sixty-gallon oil tanks, with pumps.
Small tanks for kerosene, alcohol, cutting oil, etc.
Gasoline storage system, 100 gallons or larger.
Oil cans, oil and grease guns.
Covered cans for waste, oily rags, and rubbish.
Pails of sand and chemical extinguishers for fire.
Overhead washer, hose and faucets.
Washing materials, soaps, sponges, chamois, etc.
Water heater.
Potash kettle, babbitt melting pot.
Drains, traps, etc., according to law.
Lightstand for night work on cars.
Block and tackle, chain hoists, etc.
Overhead trolley track or portable crane.
Turntable or substitute.
Steel or wooden lockers.
Oil drip pans for floors.
Dustbrush, floor broom, whisk broom.
Water pails, quart and gallon measures, funnels.
Brazing forge.
Autogenous welding outfit.
Carbon-removing outfit.
Blacksmith's forge and blower.
Post drill press and drills.
Five hundred pound anvil and block.
Quenching tank, forge coal box.

REPAIR SHOP SUPPLIES

Class A—Hardware Stock.

Round cold-rolled steel rods, ¼, 5/16, ⅜, ½ inch.
Round machinery steel bars, ⅝, ¾, ⅞, 1, 1¼ inch.
Flat band iron and steel, assorted sizes as needed.
Drill rod, assorted sizes.
Black sheet iron, sheet brass and copper, assorted gauges.
Tinned and galvanized iron sheets.
Tool steel, for lathe and planer tools.

Class A—Hardware Stock—*Continued:*

Key stock in bars, 1/4, 5/16, 3/8, 1/2-inch square.
Paper thin copper or brass for shims.
Cored bronze bars, for bushings, assorted.
Babbitt or Magnolia metal ingots.
Bare copper and iron wire, 14, 16, 18, 20 gauge.
Piano and phosphor bronze wire, for springs.
Soft wire solder; half and half solder; hard solder.
Brazing spelter, granulated and in wire.
Seamless steel tubing, sizes as needed.
Brass and copper tubing, sizes as needed.
Annealed seamless copper tubing for fuel and gas lines—1/4. 5/16, 3/8 inch.
Compression couplings for copper tubing, ells, tees, unions, etc.
Norway iron and copper rivets and burrs, assorted.
Punched iron washers—1/8, 3/16, 1/4. 5/16, 3/8, 7/16, 1/2-inch holes.
Bolts and nuts, assortment of standard sizes.
Split pins and lock washers, assortment.
Cap screws, stove bolts, carriage bolts, assortment.
Wood screws, round. flat and oval head, blued steel, brass and nickel.
Lag screws, brads, nails, escutcheon pins, upholsterer's tacks.
Set screws, taper pins, lock nuts, assortment.
Woodruff keys and cutters, assortment.
1/8-inch brass pipe, other sizes as needed.
Standard brass fittings, 1/8-inch pipe size, ells, tees, unions, pet cocks, etc.

Class B—Miscellaneous Supplies.

Emery, three grades—fine, medium and coarse.
Crocus, grindstone dust, ground glass, corborundum.
Crocus cloth, emery cloth, sand paper, assortment.
Lard oil for cutting, cutting compound.
Lubricants: cylinder oil—light medium, heavy.
Lubricants: machine oil, three-in-one, cup grease, graphite.
Lubricants: special grease for transmissions and ball bearings.
Rubber matting and linoleum for floor boards, etc.
Brass molding, for running boards, etc.
Sheet felt, assortment felt oil retaining washers.
Fiber tubes and rods, as needed.
Sheet hard rubber, black or red fiber, assorted thicknesses.
Heavy brown paper and light cardboard for packings.
Sheet asbestos, mobiline, for packings.
Sheet rubber packings for water joints and pump covers.
Asbestos cord, candle wicking, hemp packing.
Red rubber tubing for gas line, 3/16, 5/16-inch hole.

Class B—Miscellaneous Supplies—*Continued:*

Rubber steam hose for water connections.
Assorted hose clamps.
Assorted copper-asbestos gaskets and packings for popular cars.
Spark plugs, ½-inch Briggs pipe, metric and S. A. E. standard.
Dry batteries, 6 x 2½ inch, and connecters.
Aluminum solder and flux.
Sheet celluloid for top windows.
Primary and secondary cables, terminals, etc.
Circular loom, electrical tape, insulating varnish.
Round and flat leather belts and lacings.
Coil spring fan and oiler belts, couplings.
Spring clips, oil and grease cups, compression relief cocks.
Waste and cleaning cloths.

Class C—Chemicals, Paints, etc.

Carbon tetrachloride, benzine, rust remover.
Grain alcohol, white and orange shellac.
Body polish, metal polish, varnish, black enamel.
Black asphaltum paint, stove polish, exhaust pipe black.
Pearl gray cylinder enamel, other colors as needed.
Aluminum powder and banana oil lacquer.
Rubber cements, smooth-on for metal, glue for wood.
Talcum powder, borax, fuller's earth.
Putty, fire clay, asbestos cement.
Kerosene, wood alcohol, gasoline, acetone.
Paraffine wax, beeswax, tallow, resin.
Proprietary welding, brazing and soldering fluxes.
Calcium chloride and glycerine, for anti-freeze compounds.
Wood alcohol, for anti-freeze compounds.
Potash or lye, sal-ammoniac, washing soda.
Muriatic acid (soldering fluid), hydrofluoric acid (for marking tools).
Copper sulphate solution for coppering steel or iron before marking.
Sulphuric acid (chemically pure) and distilled water.

CHAPTER III.

OVERHAULING THE GASOLINE ENGINE

Taking Down the Motor—Examination and Marking of Parts—Defects in Cylinders—Carbon Deposits, their Cause and Prevention—Use of Carbon Scrapers—Denatured Alcohol—Burning Out Carbon with Oxygen—How Oxygen is Produced—Repairing Scored Cylinders—How to Repair Cracked Water Jacket—Inspecting Cylinder Packings—Valve Removal and Inspection—Reseating and Truing Valves—Valve Grinding Processes—Depreciation in Valve Operating System—Piston Troubles—Removing Piston Stuck in Combustion Chamber—Piston Ring Removal and Inspection—Fitting Piston Rings—How Wristpins are Held—Wristpin Wear—Inspection and Refitting of Engine Bearings—Adjusting Main Bearings—Crankpin Restoration—Scraping Brasses to Fit—Connecting Rod Bearings—Testing Bearing Parallelism—Ball Bearing Crankshafts—Camshafts and Timing Gears—Valve Timing Methods—Sleeve Valve Motors—Eight-Cylinder V Motors—Precautions in Reassembling Parts—Loose Flywheels—Two-Cycle Motors.

MANY car owners recognize the value of having the car overhauled before the inception of the active riding season when climatic conditions are not favorable to the continual operation of the car. In those portions of the country where cars may be kept in operation all the year round, a certain time each year should be set apart for giving the car a thorough looking over with a view of determining the points where depreciation exists, and the best methods of remedying the defective condition. The wise motorist realizes that this work of restoration is absolutely necessary, if continued satisfactory service is to be expected from the car. The motorist who shuns the expense of having the machine looked over and who operates it as long as the various parts function, is generally the one who is loudest in the condemnation of the automobile. In this chapter, the writer proposes to discuss the various steps incidental to overhauling gasoline engines of various types

and in order to do this in a way that will be of value to the motorist or novice repairmen it is necessary to treat of the various parts in logical sequence. The suggestions given are all based on a practical experience with the repair of automobiles and nothing of doubtful value will be described.

Taking Down the Motor.—In order to look over the parts of an engine and to restore the worn or defective components it is necessary to take the engine entirely apart as it is only when the power plant is thoroughly dismantled that the parts can be inspected or measured to determine defects or wear. If one is not familiar with the engine to be inspected, even though the work is done by a repairman of experience, it will be found of value to take certain precautions when dismantling the engine in order to insure that all parts will be replaced in the same position they occupied before removal. There are a number of ways of identifying the parts, one of the simplest and surest being to mark them with steel numbers or letters or with a series of center punch marks in order to retain the proper relation when reassembling. This is of special importance in connection with dismantling multiple cylinder engines as it is vital that pistons, piston rings, connecting rods, valves, and other cylinder parts be always replaced in the same cylinder from which they were removed, because it is uncommon to find equal depreciation in all cylinders. Some repairmen use small shipping tags to identify the pieces. This can be criticized because the tags may become detached and lost and the identity of the piece mistaken. If the repairing is being done in a shop where other cars of the same make are being worked on, the repairman should be provided with a large chest fitted with a lock and key in which all of the smaller parts, such as rods, bolts and nuts, valves, gears, valve springs, camshafts, etc., may be stored to prevent the possibility of confusion with similar members of other cars. All parts should be thoroughly cleaned with gasoline or in the potash kettle as removed, and wiped clean and dry. This is necessary to show wear which will be evidenced by easily identified indications in cases where the machine has been used for a time, but in others, the deterioration can only be detected by delicate measuring instruments.

A typical four cylinder automobile motor is shown at Fig. 88, with all parts in place. In taking down a motor the smaller parts and fittings such as spark plugs, manifolds and wiring should be removed first. Then the more important members such as cylinders may be removed from the crankcase to give access to the interior

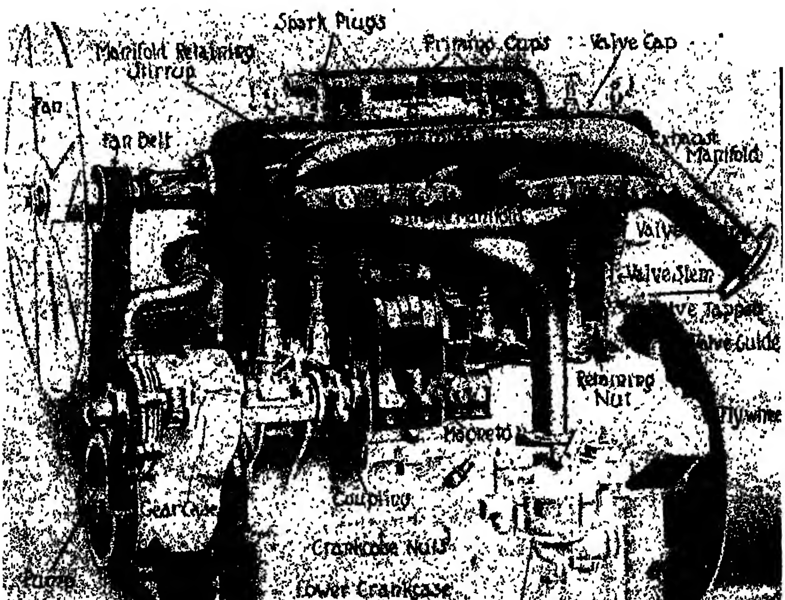


Fig. 88.—View of Typical Four Cylinder Automobile Power Plant.

and make possible the examination of the pistons, rings and connecting rods. After the cylinders are removed the next operation is to disconnect the connecting rods from the crankshaft and to remove them and the pistons attached as a unit. Then the crankcase is dismembered, in most cases by removing the bottom plate, thus exposing the main bearings and crankshaft. The first operation is the removal of the inlet and exhaust manifolds, next one uncouples the water piping from the radiator. There are various

methods of fastening manifolds on the cylinder casting, the most common being by retaining stirrups as shown in engine at Fig. 88, or by flanges and bolts as outlined in illustrations of engines at Fig. 89. As will be evident, where cylinders are of the T-head form with valves on opposite sides of the cylinder casting, the bolt and flange system is generally used. On L-head motors, where the valves are in the same extension of the cylinder casting, the bolt and stirrup retention method is generally followed. One may safely say that engines of low and moderate priced cars, being of the L-head form will have the manifold retained by stirrups and bolts, whereas the T-head power plant of the larger and higher priced cars will use the bolted manifold construction.

It is now common practice to cast all cylinders together, blocks of four being very common and blocks of six are not rare enough to cause comment. In some cases the manifolds are cored integral with the cylinder casting and it is merely necessary to remove a short pipe leading from the carburetor to one inlet opening and the exhaust pipe from the outlet opening common to all cylinders. In order to remove the carburetor it is necessary to shut off the gasoline supply at the tank and to remove the pipe coupling at the float chamber. It is also necessary to disconnect the throttle operating rod. After the cylinders are removed and before taking the crankcase apart it is well to remove the water pump, magneto, and mechanical oiler if that system of lubrication is used. The wiring on most engines of modern development is carried in conduits and usually releasing two or three minor fastenings will permit one to take off the plug wiring as a unit. The wire should be disconnected from both spark plugs and magneto distributor before its removal. The appearance of the engine shown at the bottom of Fig. 89, after the magneto ignition wiring, spark plugs and front of timing gear case are removed is shown at Fig. 91, A. The next operation in dismantling this engine is to take off the four nuts holding the induction manifold to the cylinder castings and when the manifold is removed the carburetor comes with it. The appearance of the engine after this has been done is shown at Fig. 91, B. The next parts to be taken off, the cylinder castings, are shown shaded in this view. The appearance of this engine after

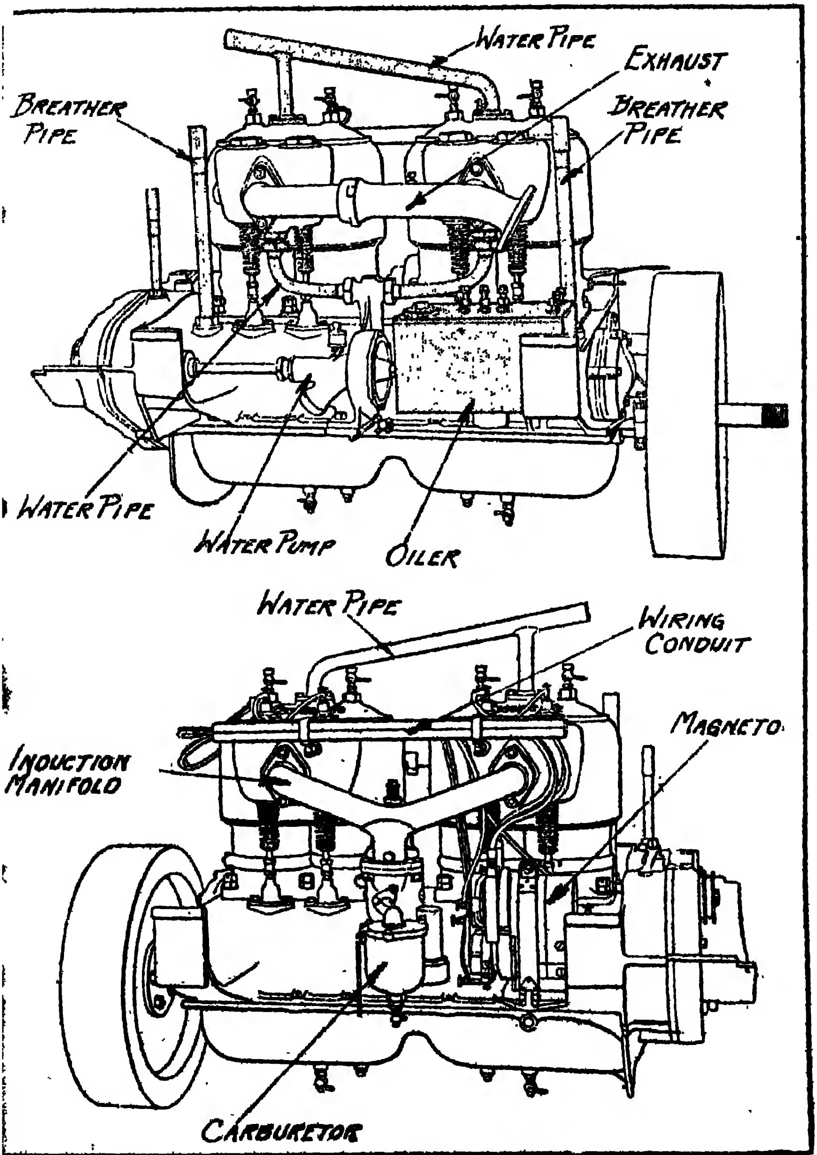


Fig. 89.—Exhaust and Intake Sides of Locomobile Four Cylinder Motor.

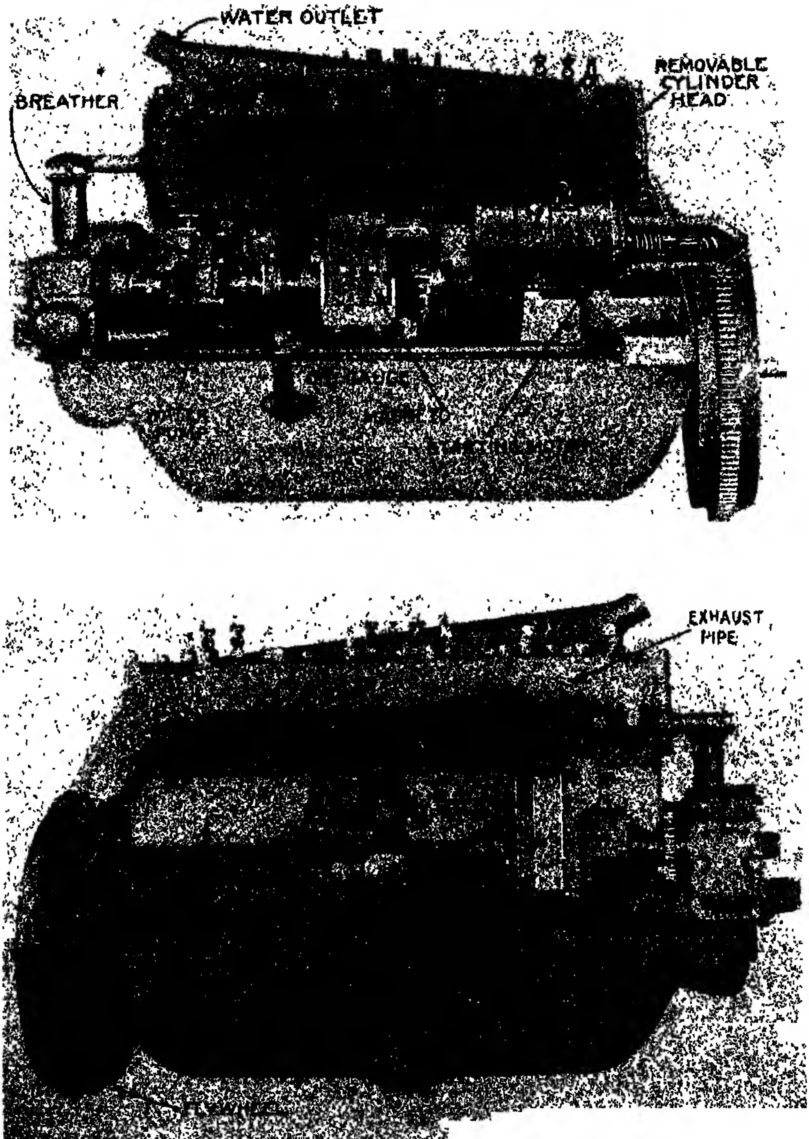


Fig. 90.—Views of Overland Model 82 Six Cylinder Motor, Showing Typical Block Motor Design.

ie cylinders have been removed is clearly indicated at Fig. 92. n this case the magneto or water pump has not been disturbed. pistons, piston rings, and connecting rods are clearly exposed ind their condition may be readily noticed.

Before disturbing the arrangement of the timing gears, it is nportant that these be marked so that they will be replaced in xactly the same relation as intended by the engine designer. If he gears are properly marked the valve timing and magneto seting will be undisturbed when the parts are replaced after overauling. When an engine has been taken down to the point shown it Fig. 92, it is possible to ascertain if there is any undue wear resent in the connecting rod bearings at either the wrist pin or rank pin ends and also to form some idea of the amount of carbon leposits on the piston top and back of the piston rings. Any wear f the timing gears can also be determined. The removal of the oottom plate of the engine enables the repairman to see if the ain bearings are worn unduly. Often bearings may be taken up ufficiently to eliminate all looseness. In other cases they may be vorn enough so that careful refitting will be necessary.

All engines are not of the type shown at Figs. 88 and 89. Where he crankcase is divided horizontally into two portions, the upper ne serving as an engine base to which the cylinders and in fact ill important working parts are attached, the lower portion, perorms the functions of an oil container and cover for the internal nechanism. There is a tendency on the part of modern designers o combine the cylinders and a portion of the crankcase in one asting, using a detachable cylinder head construction in order to oermit valve grinding and carbon removal without taking the engine out of the chassis frame. The connecting rods and pistons may ilso be removed where this construction is followed through the opening left after the detachable cylinder head is removed. In he engine shown at Fig. 93, not only the cylinders but practically he entire engine crankcase, except for the plate closing the botom is cast in one unit. It will be evident that the removal of he bottom plate and cylinder head will provide access to the nterior of the motor. Attention is directed to the inlet manifold nstruction which is cored in the cylinder block. The exhaust

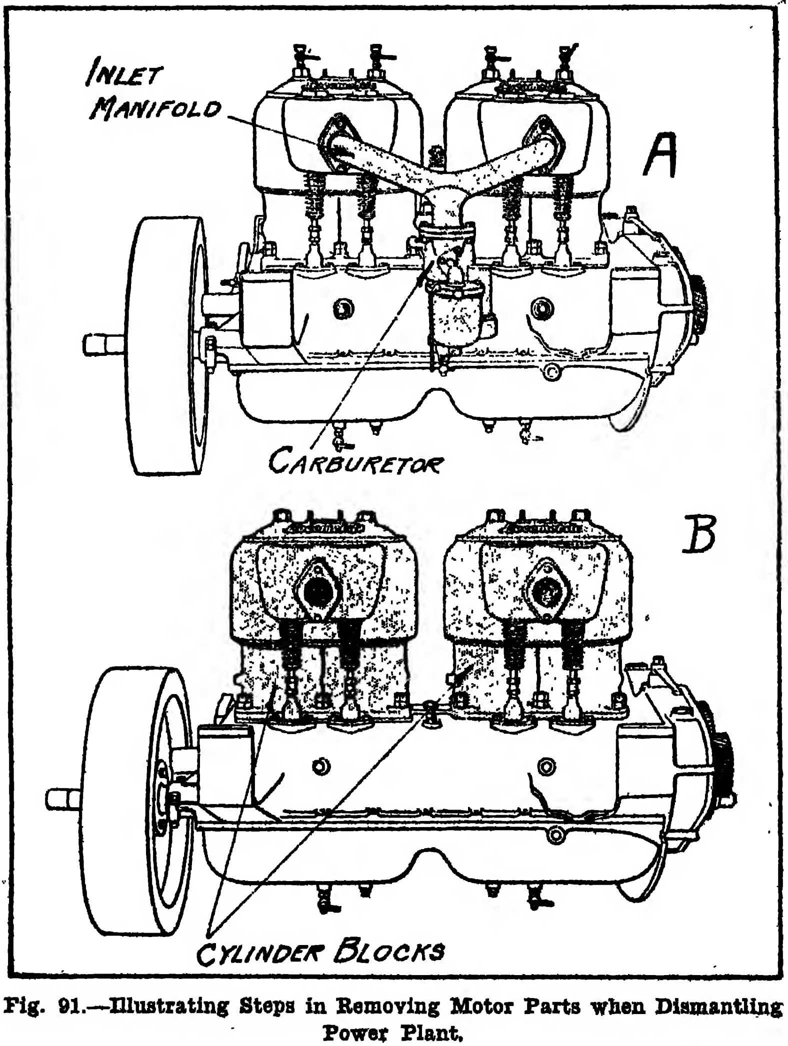


Fig. 91.—Illustrating Steps in Removing Motor Parts when Dismantling Power Plant.

manifold however, is a separate casting secured to the cylinde block in the usual way.

The important parts of an engine of the conventional fou cylinder pattern where the cylinders are cast in pairs are clearl

shown at Fig. 94, and their appearance may be readily noted. It will be evident that when the bottom of the crankcase is removed the crankshaft is exposed and the main bearing caps may be released by unscrewing the bearing cap retention bolts. A number of parts of typical engines are also indicated at Fig. 95. The view at A, shows the appearance of the usual arrangement of the

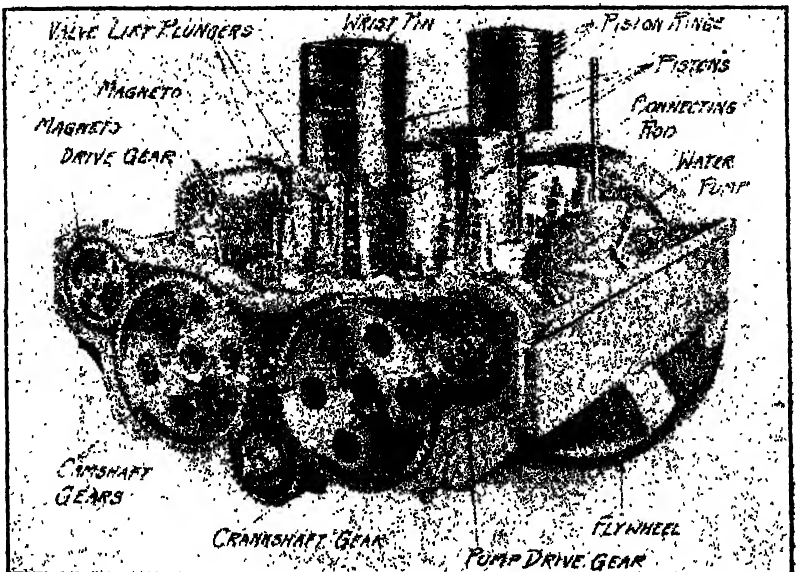


Fig. 92.—View of Automobile Engine with Cylinders Removed to Expose Pistons and Connecting Rod and with Timing Gear Case Taken Off to Expose Gearing.

timing gears when cylinders of the T-head form are employed. As will be apparent one large gear is carried by each camshaft, these being turned by a pinion of half their size on the crankshaft. The method of retaining the timing gear varies with the construction of the engine. In the form shown at A, the gears are held on the flanged camshaft end by three square head cap screws which are wired together to prevent loosening. In the construction shown at Fig. 92, the camshaft gears are securely held by four

castellated retention nuts which screw on studs projecting from the camshaft flange end. The smaller gears, such as the magneto drive and pump drive are usually held by a key which is set into a taper shaft and the gears are tightly clamped on the taper by substantial clamping nuts.

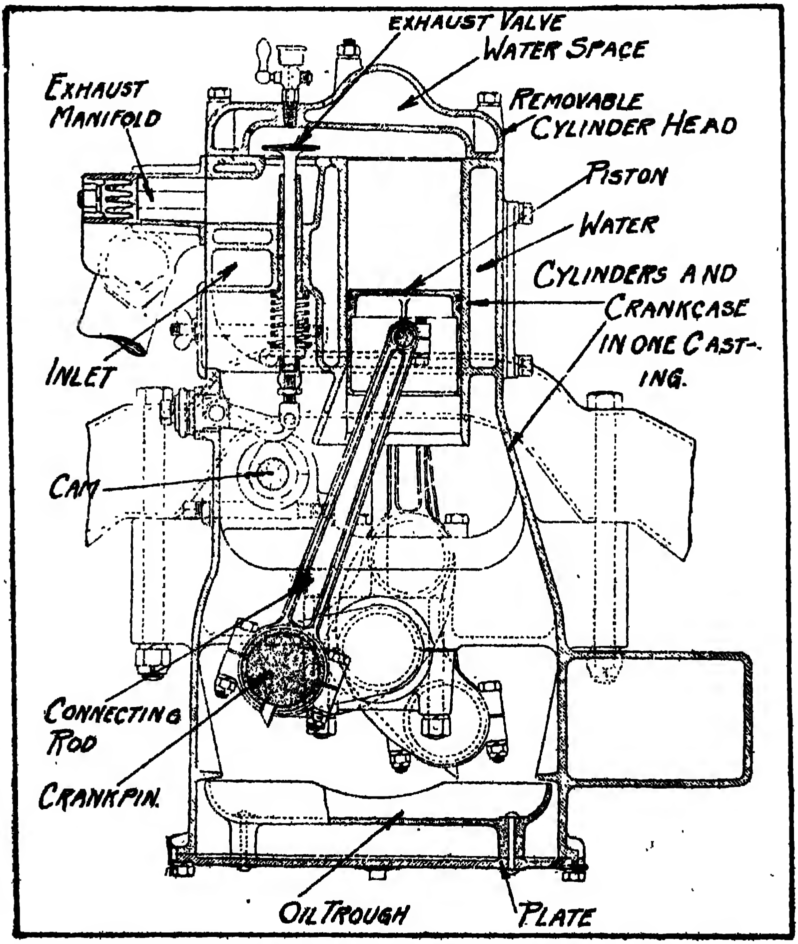


Fig. 93.—End Sectional View of Lewis Six Cylinder Motor Showing Unconventional Construction in Which Cylinders and Crank Case are Formed Integral.

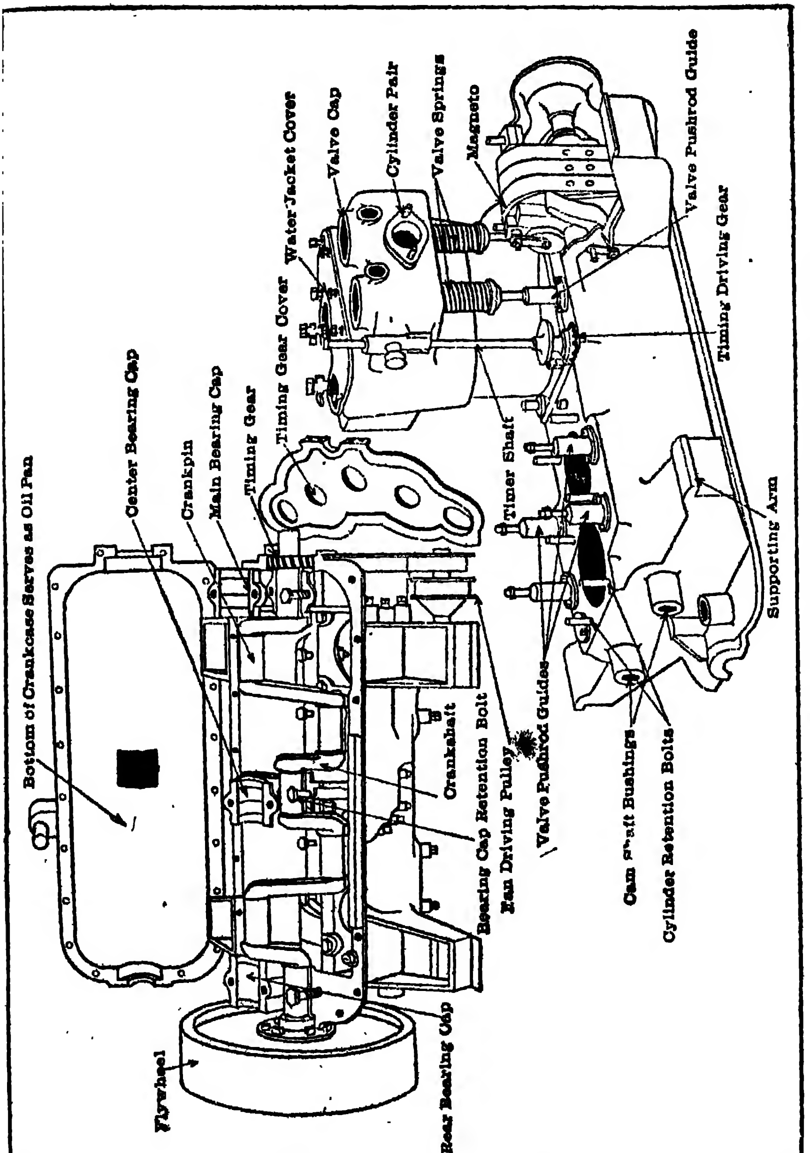


Fig. 94.—Views of Partially Dismantled Automobile Engine.

Attention has been previously called to the necessity of marking the timing gears. The manner in which this can be done is clearly indicated at Fig. 95, B. It will be seen that the crankshaft gear is provided with two figures, "1" and "1," opposite cer-

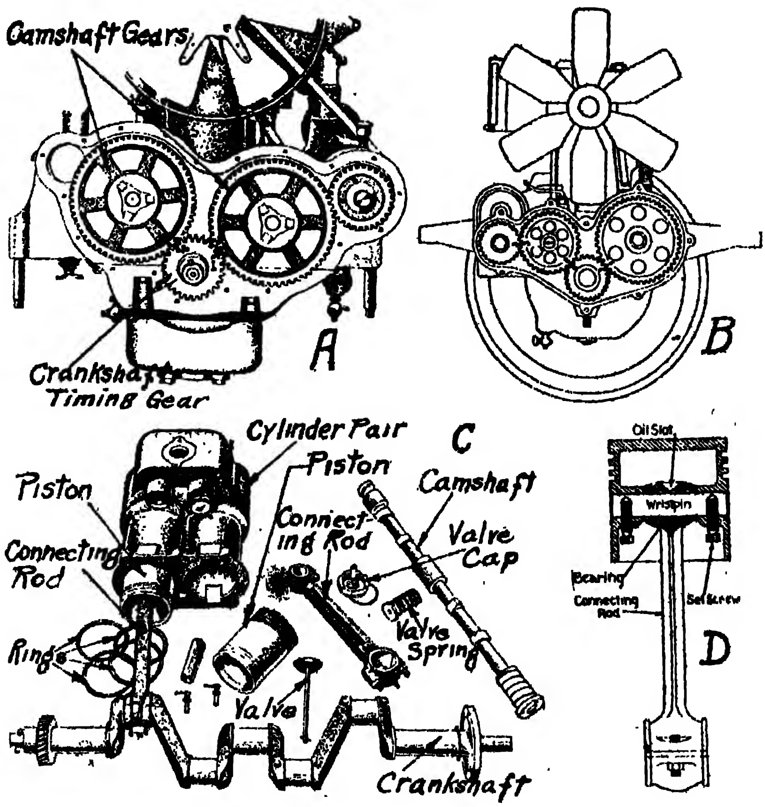


Fig. 95.—Showing Method of Marking Timing Gears and Group of Miscellaneous Motor Parts.

tain teeth. The camshaft drive gear is provided with a numeral 1 to indicate the space that the tooth marked 1 on the crankshaft gear should occupy. Similarly the intermediate gear which transmits motion to the magneto drive gear is marked with a 2 and 3 which

should correspond to the corresponding numerals on the crank-shaft gear and member driving the magneto armature. At C, Fig. 95, is shown a group of the important internal parts of the engine. These are plainly marked and should be readily recognized by even the novice. At Fig. 95, D, a typical piston and connecting rod assembly is depicted. In this view, the parts are also identified and further description is unnecessary.

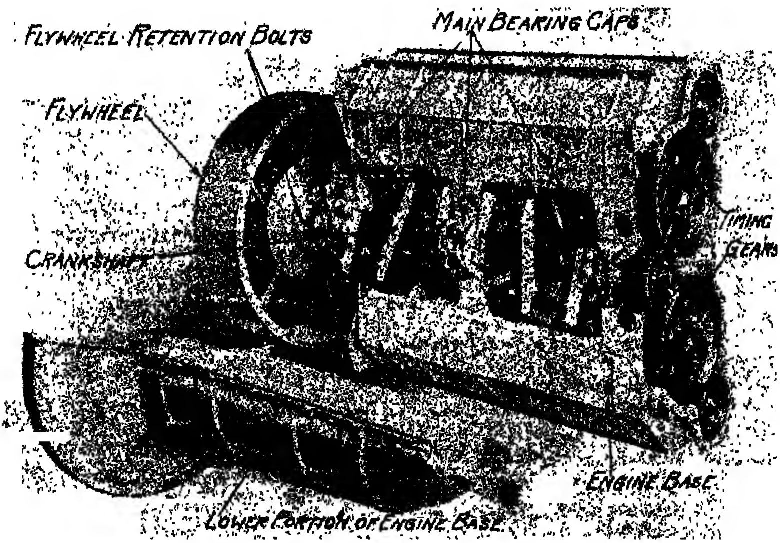


Fig. 96.—Lower Portion of Engine Base Removed to Show Crankshaft and Accessibility of Main Bearings.

The illustration at Fig. 96, is that of the crankcase shown at Fig. 92, as it looks when viewed from the bottom after the lower portion of the crankcase has been removed. As will be apparent, the main bearing caps that hold the crankshaft in place may be released by taking off the retention nuts and the connecting rod bearing caps which keep these members attached to the crank pins are also exposed for inspection.

In some multiple cylinder engines the cylinders are cast individually and instead of the crankshaft having three main bearings,

as in the engine shown at Fig. 96, it has five main bearings as indicated in the sectional view of the Overland engine shown at Fig. 97. When the cylinders are cast individually it is possible to replace a defective cylinder without sacrificing the remainder as is imperative if the cylinders are cast in block. Individual cylinders

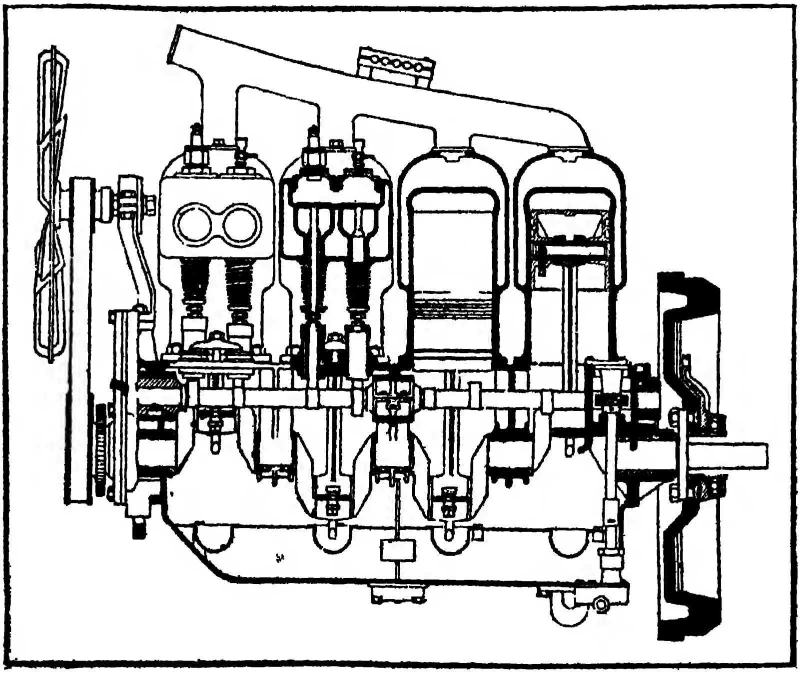


Fig. 97.—Longitudinal Sectional View of Overland Four Cylinder Motor, a Type Having Individual Cylinder Castings and a Five Bearing Crankshaft.

are more easily handled, but where these are used it is absolutely necessary to mark them so that they will always be replaced in proper position. In most cases, the cylinders are duplicates of each other and if they were not marked it would not be difficult to transpose them on the engine base, an undesirable proceeding.

In order to familiarize the motorist or novice repairman with engine construction a side sectional view of a typical power plant

in the position it occupies in the car frame is shown at Fig. 98, while a front sectional view is shown at Fig. 99. This engine is a four cylinder T-head form and is the same as that outlined in illustrations at Fig. 90, which clearly indicate the external appearance of the power plant. The various important parts are indicated and should be easily identified when working on engines of this type. One of the most widely used of automobile power plants

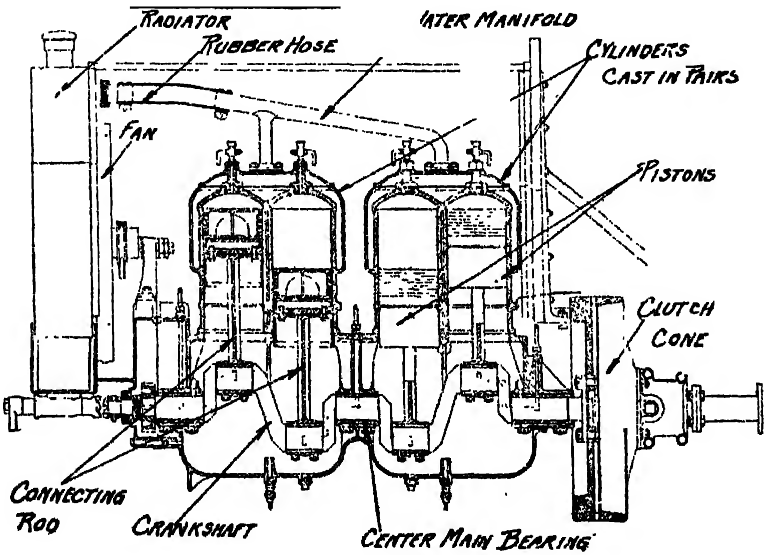


Fig. 98.—Longitudinal Sectional View of Locomobile Four Cylinder Motor Which Has Cylinders Cast in Pairs and a Three Bearing Crankshaft.

and one that practically all repairmen will have occasion to work on at some time or other owing to the thousands in use in all parts of the world is that employed on the Ford Model T-automobile. This power plant is shown in part sectional view at Fig. 100. It is a unit power plant, as the planetary change speed gearing is carried in an extension of the engine crankcase. The four cylinders and upper portion of the crankcase are cast as a unit. The cylinder head is removable. One of the novelties of construc-

tion in this motor is the use of a flywheel magneto, the balance member carrying a series of U-shaped magnets which revolve past a series of fixed field coils attached to a plate which does not rotate on account of being bolted to the engine crankcase. The general construction of the engine may be readily ascertained by careful inspection of the illustration.

Defects in Cylinders.—After the cylinders have been removed, and stripped of all fittings, they should be thoroughly cleaned and then carefully examined for the defects enumerated at Fig. 101.

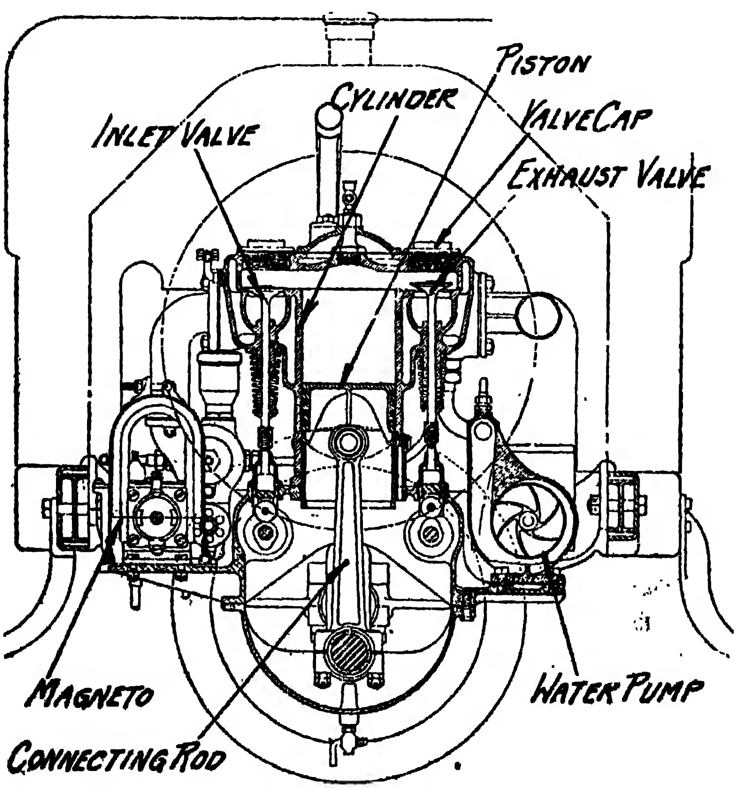


Fig. 99.—Front Sectional View of Locomobile Four Cylinder Motor.

The interior or bore should be looked at with a view of finding score marks, grooves, cuts or scratches in the interior, because there are many faults that may be ascribed to depreciation at this point. The cylinder bore may be worn out of round, which can only be determined by measuring with an internal caliper or dial indicator even if the cylinder bore shows no sign of wear. The flange at the bottom of the cylinder by which it is held to the engine base may be cracked. The water jacket wall may have opened up due to freezing of the jacket water at some time or other or it may be filled with scale and sediment due to the use of impure cooling water. The valve seat may be scored or pitted, while the threads holding the valve chamber cap may be worn so that the cap will not be a tight fit. The cylinder described is an individual casting of the L-head form having integrally cast water jacket.

Other forms of unit cylinders have been evolved, one of the most widely used being that of the four cylinder Cadillac engines, which is shown at Fig. 102. This incorporates several novelties in construction, one being the applied sheet copper water jacket, the other being the detachable cylinder head casting which is screwed down against the top of the copper water jacket and held in place on the cylinder by an externally threaded close nipple. The advantages that were claimed for this construction are easy replacement of one defective cylinder assembly part without scrapping the rest. For example, when the cylinder construction shown at Fig. 101 is used, if the cylinder bore is badly scored, the entire casting must be thrown away, even though the water jacket, combustion and valve chambers are in perfect condition. With the Cadillac construction, should the water jacket be faulty it is impossible to repair this easily owing to the material employed or to replace it if repairs are not practical. If the cylinder should be scored, the water jacket and combustion head may be saved and a new cylinder casting purchased at considerably less cost than that of the complete unit cylinder.

Many motors have been made by the Knox Company, using individually cast cylinders of the form shown in section at Fig. 103, A, and completely assembled at B, in one view and with cylinder head removed in the other. This detachable head con-

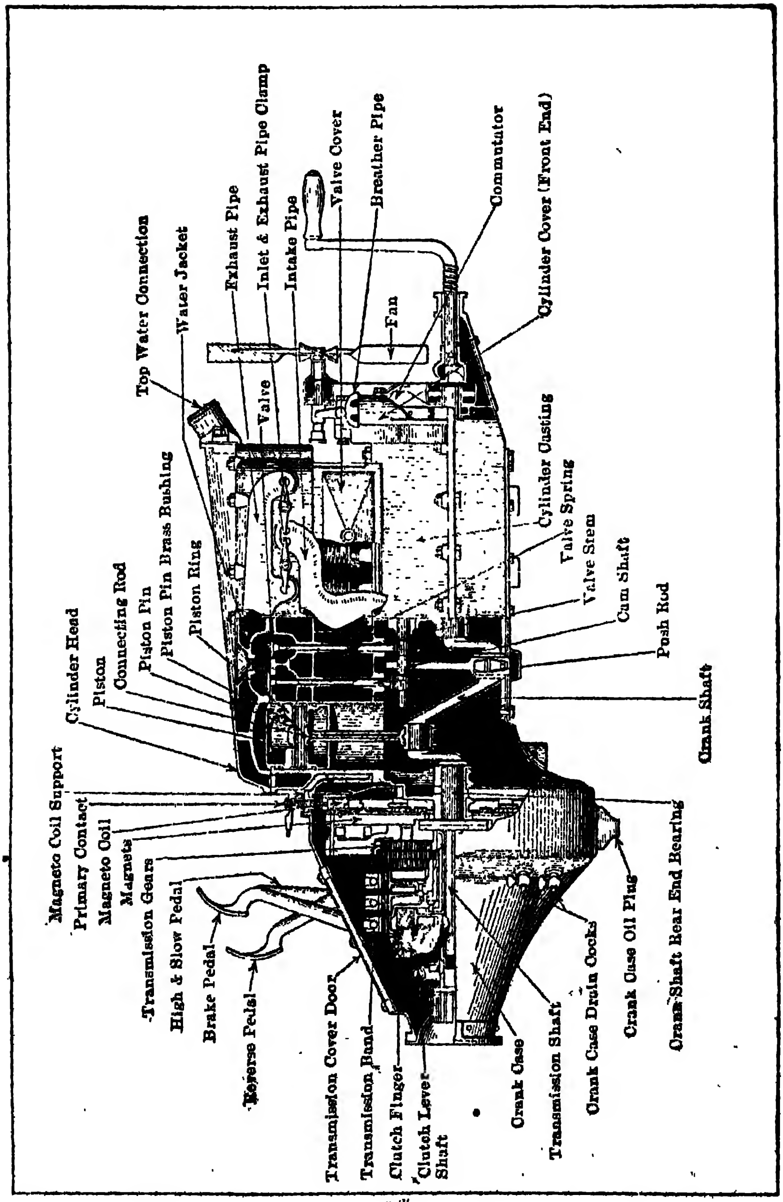


Fig. 100.—Partly Sectional View of the Ford Four Cylinder Unit Power Plant.

struction was necessary on account of having the valves seat directly against flat seatings machined in the head casting. The head casting is provided with its own water jacket, as is the cylinder, connections being made between the two by a short bent pipe held in place by the same stirrup member that holds the manifold to the cylinder. The detachable head construction makes it possible to remove that member and obtain ready access to the piston tops for scraping out carbon without taking the main cylinder portion from the crankcase. When the valves need grinding the head may be removed and carried to the bench where the work may be performed with absolute assurance that none of the valve grinding compound will penetrate into the interior of the cylinder as is sometimes unavoidable with the L-head cylinder shown at Fig. 101, or the T-head form outlined at Fig. 99, in which the valve seatings are in pockets cast integrally with the cylinder.

The detachable head construction has only recently become popular, though it was one of the earliest forms of automobile engine construction. In the early days it was difficult to procure gaskets or packings that would be both gas and water tight. The sheet asbestos commonly used was too soft and blew out readily. Besides a new gasket had to be made every time the cylinder head was removed. Woven wire and asbestos packings impregnated with rubber, red lead, graphite and other filling materials were more satisfactory than the soft sheet asbestos but were prone to burn out if the water supply became low. Materials such as sheet copper or brass proved to be too hard to form a sufficiently yielding packing medium that would allow for the inevitable slight inaccuracies in machining the cylinder head and cylinder. The invention of the copper-asbestos gasket, which is composed of two sheets of very thin, soft copper bound together by a thin edging of the same material and having a piece of sheet asbestos interposed solved this problem. One of the first engines to use the detachable cylinder head piece was the Ford, and at the time it was first introduced it was met with considerable criticism on the part of automobile engineers. That this proved unfounded and based on personal prejudice is clearly demonstrated at this time by the wide use of the detachable head construction. Copper-asbestos

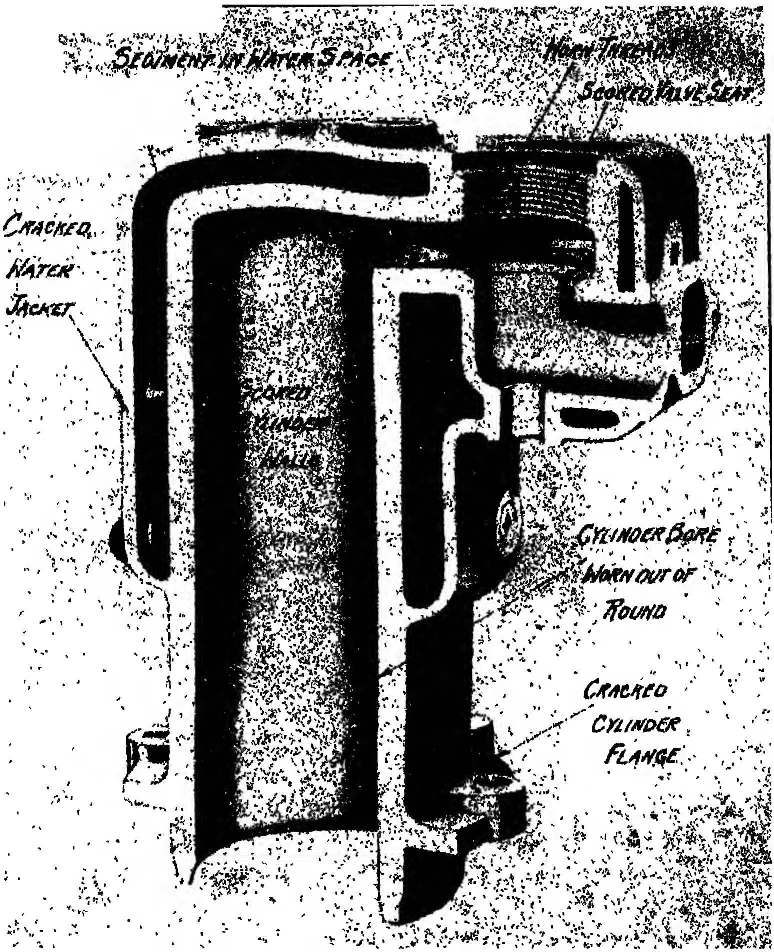


Fig. 101.—Sectional View of Automobile Engine Cylinder, Showing Defects that Will Reduce Engine Efficiency.

packings form an effective seal against leakage of water and a positive retention means for keeping the explosion pressure in the cylinder.

The great advantage of the detachable head is that it permits of very easy inspection of the piston tops and combustion chamber

interiors which can only be done with cylinders of the L, or T, form by removing the cylinder from the engine base. Two forms of removable cylinder heads are shown at Fig. 104. They are similar in design and utilize the same form of gasket, the only difference being that the type shown at A, serves two cylinders while the one outlined at B, covers the four cylinders. The construction at A, is used on the Oakland car while that at B, is found on the Ford, Metz, Regal, Cartercar, Maxwell, Oakland and several others. The cylinder heads are securely held by substantial retention bolts and if these are properly tightened and the gasket is in good condition there is not likely to be any loss in pressure due to leakage. One of the most important things to look for when the cylinder has been removed or the cylinder head taken off, if that method of construction is followed, is carbon deposits These accumulate at the various points indicated at Fig. 105, namely the piston top, valves, around the spark plug and at several points in the combustion chamber.

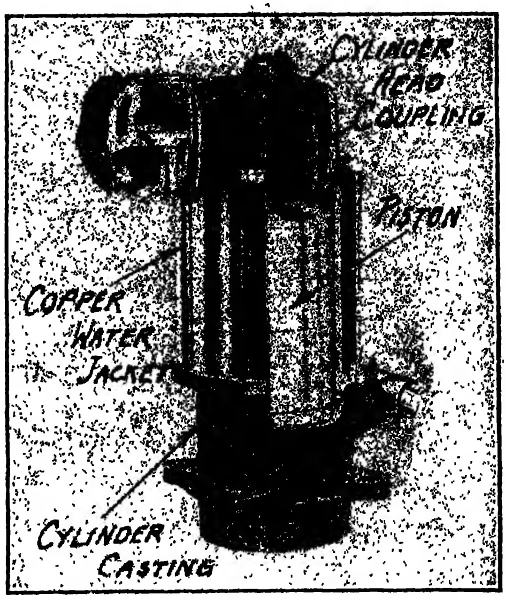


Fig. 102.—Cylinder of Cadillac Four Cylinder Motor Using Applied Copper Water Jacket.

Carbon Deposits, Their Cause and Prevention.—Most authorities agree that carbon is the result of imperfect combustion of the fuel and air mixture as well as the use of lubricating oils of improper flash point. Lubricating oils that work by the piston rings may become decomposed by the great heat in the combustion chamber but at the same time one cannot blame the lubricating

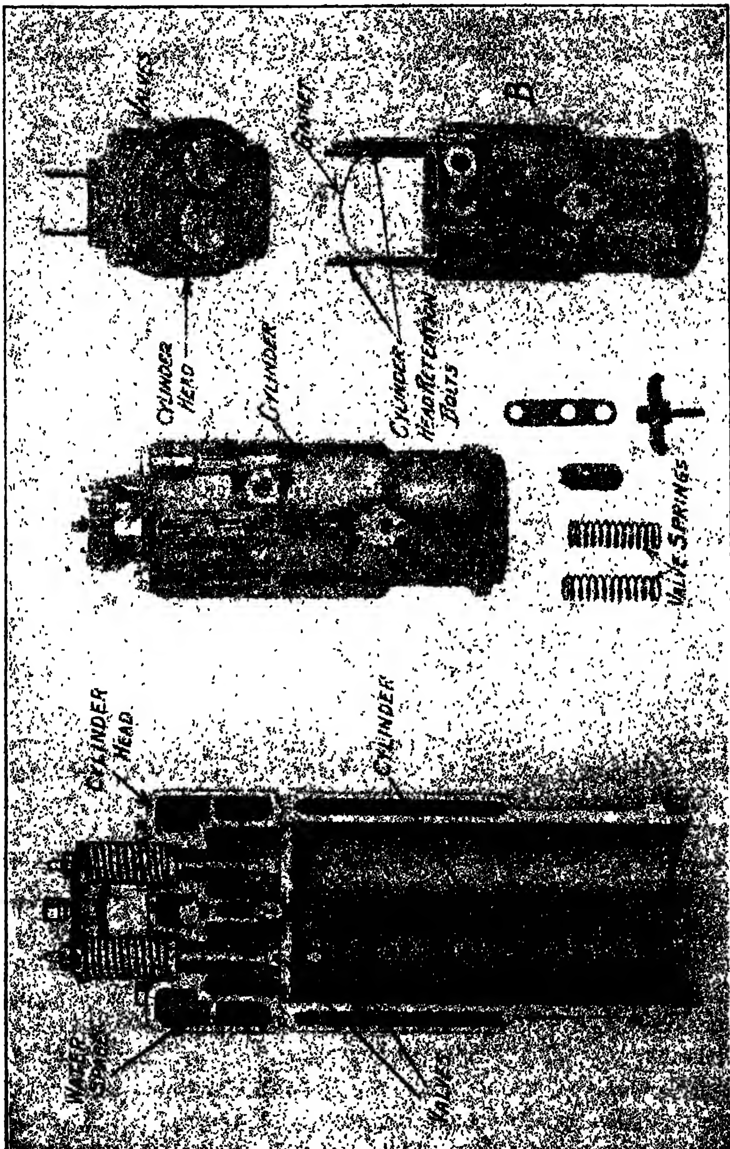


Fig. 103.—Views Outlining Construction of Knox Detachable Head Motor Cylinder.

oil for all of the carbon deposits. There is little reason to suspect that pure petroleum oil of proper body will deposit excessive amounts of carbon, though if the oil contains a resinous or animal fat filler there would be much carbon left in the interior of the combustion chamber. Fuel mixtures that are too rich in gasoline also produce these undesirable accumulations.

A very interesting chemical analysis of a sample of carbon scraped from the interior of a motor vehicle engine shows that ordinarily the lubricant is not as much to blame as is commonly supposed. The analysis was as follows:

Oil	14.3%
Other combustible matter	17.9
Sand, clay, etc.	24.8
Iron oxide	24.5
Carbonate of lime	8.9
Other constituents	9.6

It is extremely probable that the above could be divided into two general classes, these being approximately 32.2% oil and combustible matter and a much larger proportion or 67.8% of earthy matter. The presence of such a large percentage of earthy matter is undoubtedly due to the impurities in the air, such as road dust which has been sucked in through the carburetor. The fact that over 17% of the matter which is combustible was not of an oily nature lends strong support to this view, while the ratios of the constituents of the incombustible material to one another is very nearly what would be expected in débris from ordinary macadam roads. If one assumes that half of the combustible matter, not of oily derivation, comes from the road dust and that one-fifth of the oxide of iron also arises from this source, the approximate composition of this cylinder deposit may be expressed as follows:

Residual matter from oil	23%
Iron dust due to friction in cylinder	20
Road dust	57

It will be evident that fully 50% of this deposit can be attributed to the ordinary dust of the highway and not to excessive fuel or an impure grade of lubricating oil. While it is imperative to

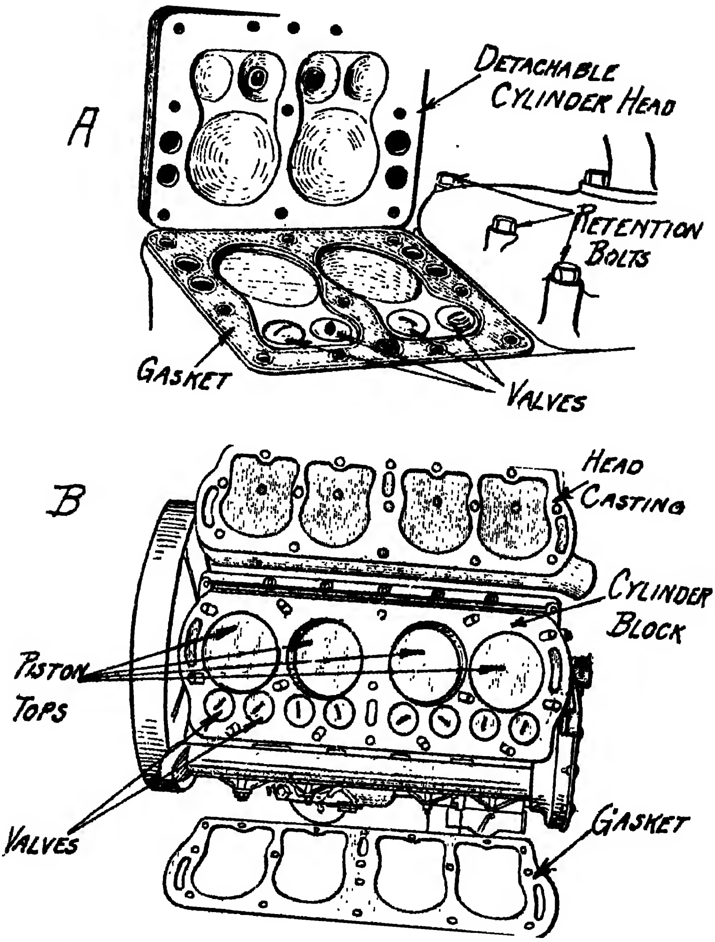


Fig. 104.—Showing Utility of Detachable Cylinder Heads and How They Make for Superior Accessibility of Valves and Combustion Chambers.

use as little gasoline in the mixture as possible and to supply only the proper quantities of high grade lubricating oil, it will be evident that even if these precautions were carefully observed

there would still be considerable deposit as the result of the impurities drawn in through the carburetor. It is very good practice to provide a screen on the air intake to reduce the amounts of dust sucked in with the air as well as observing the proper precautions relative to supplying the proper quantities of air to the mixture and of not using any more oil than is needed to insure proper lubrication of the internal mechanism.

Use of Carbon Scrapers.—It is not unusual for one to hear an automobile driver complain that the car he drives is not as responsive as it was when new after he has run it but very few months. There does not seem to be anything actually wrong with the car, yet it does not respond readily to the throttle and is apt to overheat. While these symptoms denote a rundown condition of the mechanism, the trouble is often due to nothing more serious than accumulations of carbon. The remedy is the removal of this matter out of place. While the surest way of cleaning the inside of the motor thoroughly is to remove the cylinders, if these members are cast integrally with the head or of removing the head member if that is a separate casting, to expose all parts, there are other methods that have been recommended that may be depended on to reduce the amount of carbon deposits. A number of carbon solvents of a secret composition have been offered which may be introduced into the cylinder through the spark plug openings or valve cap holes

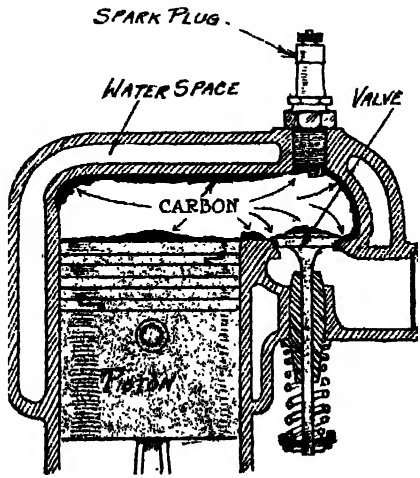


Fig. 105.—Sectional View of Upper Portion of Cylinder Showing Point Where Carbon Deposits Accumulate.

that are said to soften the accumulation, and permit it to be blown out through the exhaust when the engine is again started after the material is used. The writer believes that there is more or less "fake" about these compositions as chemical analysis of some has disclosed the composition, which on careful study of cause and

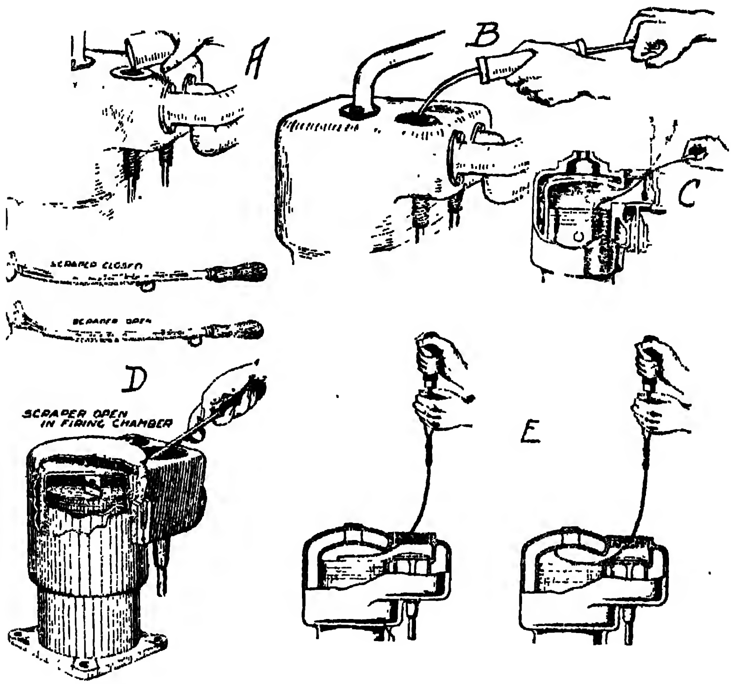


Fig. 106.—Outlining Use of Scrapers in Removing Carbon Deposit from Combustion Chamber Interior.

effect, does not seem to justify all the claims made for them by the enthusiastic advertising men responsible for their promotion. One widely advertised carbon remover of liquid form was found to be composed largely of acetone. Another was practically deodorized kerosene and denatured alcohol mixture. Another of granulated form was discovered to be practically common salt. There is no

question in the writer's mind but that a solvent like acetone would soften carbon deposit enough so it could be readily removed by scraping. The method of using the solvent is to bring the piston in the cylinder to be cleaned up to the end of its compression stroke at which time both valves are closed and to pour in a definite quantity of the solvent through a valve cap or spark plug opening. This operation is outlined at Fig. 106, A. After the liquid has been allowed to soak thoroughly into the carbon deposits for periods varying from two to six hours it is drawn out of the cylinder by means of a syringe as shown at Fig. 106, B. When the engine is started after all cylinders have been treated in turn the exhaust will be very smoky and filled with carbon particles, this indicating that considerable quantities of the carbon has been dissolved. This treatment is not always successful, as it would be more apt to remove the soluble carbon, as is due from burnt lubricating oil, or rich mixture than it would be to act upon the earthy material that the chemical analysis shows, exists in the deposits.

In certain forms of cylinders, especially those of the L, or T form, it is possible to introduce simple scrapers down through the valve chamber cap holes and through the spark plug hole if this component is placed in the cylinder in some position that communicates directly to the interior of the cylinder or to the piston top. This method is particularly applicable to engines having valves on opposite sides, namely those employing cylinders of the T form. No claim can be made for originality or novelty of this process as it has been used for many years on large stationary engines. The first step is to dismantle the inlet and exhaust piping and remove the valve caps and valves, although if the deposit is not extremely hard or present in large quantities one can often manipulate the scrapers in the valve cap openings without removing either the piping or the valves. Commencing with the first cylinder, the starting crank is turned till the piston is at the top of its stroke, then the scraper may be inserted, as indicated at Fig. 106, C, and the operation of removing the carbon started by drawing the tool toward the opening. As this is similar to a small hoe, the cutting edge will loosen some of the carbon and will draw it toward the opening. A swab is made of a piece of cloth or waste fastened at

the end of a wire and well soaked in kerosene to clean out the cylinder. When the engine is of a T-head type and the valves are removed it is possible to introduce a ball of waste at one part and push it clear through the cylinder and out of the other valve port, this bringing much loosened carbon out with it.

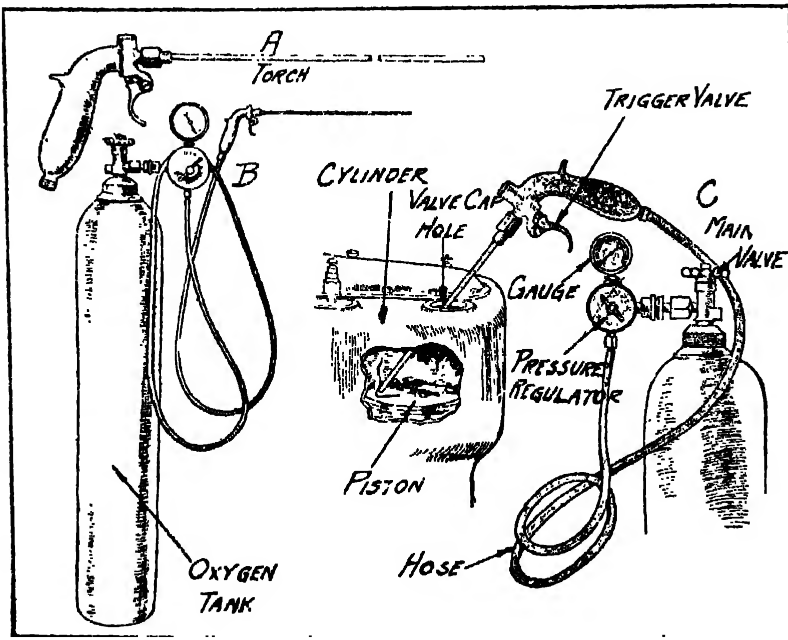


Fig. 107.—How Oxygen May be Used to Remove Carbon by a Combustion Process.

When available, an electric motor with a length of flexible shaft and a small circular cleaning brush having wire bristles can be used in the interior of the engine. The electric motor need not be over one-eighth horsepower running at 1,200 to 1,600 R. P. M., and the wire brush must, of course, be of such size that it can be easily inserted through the valve chamber cap. The flexible shaft permits one to reach nearly all parts of the cylinder interior without difficulty and the spreading out and flattening of the brush insures that considerable surface will be covered by that member.

While the carbon scrapers may be easily made by any mechanic, patented forms are available at small cost which have advantages worthy of consideration. The tool shown at Fig. 106, D, is known as Vail's carbon scraper and was designed for use in any T, or L, head motor by removing the valve caps and turning the motor over until the piston comes to the top center. The scraper is then inserted in a closed condition through either valve port and after it is inside the combustion chamber the expanding bar may be pulled back and the scraper blades will spread enough to conform to the size of the firing chamber. Moving the scraper vigorously back and forth and around the side wall for a few minutes loosens the carbon deposit. When this has been done all carbon should be scraped into the valve chamber with the closed scraper end and either spooned out with that member or blown out with compressed air. A soft cloth saturated with kerosene is then placed between the blades of the scraper, turning that member into a mop and if reinserted into the cylinder will remove any of the fine particles of carbon which might be left therein. The device is made of high grade spring steel with hardened cutting blades and has a considerable degree of flexibility. Still another form of flexible carbon scraper is shown at E, this

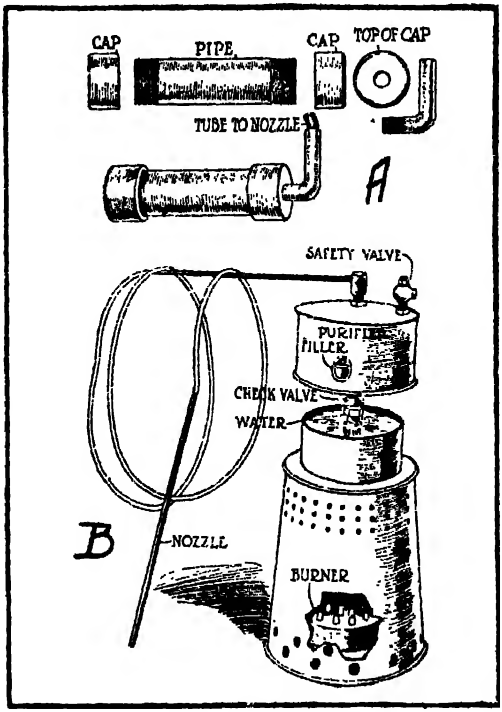


Fig. 108.—Simple Oxygen Generator.

consisting of a flexible steel blade having a sharp hoe shaped end which is inserted through the valve cap opening and used in the manner indicated in the illustration.

Use of Denatured Alcohol in Removing Carbon.—In a paper read before the National Gas Engine Association, Joseph A. Anglada described the use of denatured alcohol as a solvent for removing the carbon deposits from the combustion chamber of explosive motors. The trials were made with single cylinder horizontal engines but there is no reason to doubt that equally as good results could be obtained in automobile power plants. The operation is described as follows:

Both of these engines were operated under a load applied by pressing a wooden lever against the fly wheel until the temperature of the jackets warmed to about one hundred and fifty degrees Fahrenheit. The engines were then stopped with the piston at the head end of the compression stroke. Both valves were closed. The compression space of each cylinder was then filled with Pyro denatured alcohol, which in the case of the International Harvester engine was left to soak for six hours and in the case of the Jacobson engine, about three and one-half hours. It was found that the exhaust valve of the International Harvester engine did not seat properly, because when the alcohol was first put in this engine it leaked past the exhaust valve. This leak, however, soon stopped, probably due to the alcohol washing away whatever foreign matter was lodged between the valve and its seat.

At the end of these periods, both engines were cranked by hand for a few revolutions and then started in the usual way, on gasoline. The exhaust in both instances, when the engine was started, contained a large quantity of black smoke and upon opening the compressed relief cock of each engine a bombardment of small incandescent particles of carbon was seen and felt on each firing stroke, showing that the alcohol had loosened the carbon deposits in these engines. In each case some of the alcohol leaked past the piston into the crank case, showing that the piston rings were not liquid tight. In this connection it is advisable to note that almost invariably lubricating oil will collect in the piston ring grooves where it becomes partially solidified in the form of a

gummy material of sufficient strength to prevent the proper operation of the piston rings. The result is that the lubricating oil which is fed to the cylinder is called upon in a very large measure to assist the piston rings in making a gas-tight joint with the cylinder wall. When denatured alcohol is introduced into the cylinder in sufficient quantity, it will dissolve the gummy deposit and permit the piston rings to slide freely in their grooves and thus fit themselves more perfectly to the cylinder walls. That this occurs has been proven by tests on a number of automobile motors which after treatment with denatured alcohol have shown an increase in power as well as in flexibility.

From a very complete series of experiments conducted with automobile motors which had been in service for different lengthy periods of time, in addition to experiments conducted with a few marine and stationary motors, I have arrived at the following conclusions:

(1) Denatured alcohol is an efficient decarbonizer for all types of gasoline engines.

(2) It does not injuriously affect the surfaces of the metals with which it comes in contact.

(3) Heat is not necessary when using denatured alcohol as a decarbonizer.

(4) Heat accelerates the action of denatured alcohol when used as a decarbonizer.

(5) Denatured alcohol when introduced in the combustion space of an automobile cylinder which is at the working temperature of the engines will loosen the carbon deposits so as to permit the deposit to become separated from the walls of the combustion space and pass out of the cylinder with the exhaust gases when the engine is run.

(6) The best results from the use of denatured alcohol, a carbon remover, are obtained when the combustion space of a hot engine is entirely filled with liquid denatured alcohol and permitted to soak for a period of not less than six hours.

(7) Denatured alcohol will act as a carbon remover when the engine is cold, provided the liquid denatured alcohol is in contact with the carbon covered surfaces. The action of denatured alcohol

under these conditions is about half as rapid as when the engine is hot.

(8) The action of denatured alcohol as a carbon remover when introduced in small quantities into the combustion space of a cold automobile engine is positive, but slow.

(9) Where the fit between the piston rings and cylinder walls is imperfect, denatured alcohol will leak past the pistons into the crank case and cause the oil in the crank case to become unfit for use for lubricating the engine. However, when a sufficient amount of denatured alcohol has been added to this oil and circulated through the lubricating system of the motor for a very short time, in order to obviate the possibility of damaging the wearing surfaces of the engine, denatured alcohol acts as a cleansing agent, as evidenced by the unusual amount of foreign matter withdrawn with the denatured alcohol treated oil and the subsequent improved action of the engine.

(10) Due to the cleansing action of denatured alcohol as noted in the preceding conclusions, an engine which has been in service for an extensive period will show a marked increase in operating efficiency when thoroughly treated with denatured alcohol.

(11) It is advisable to introduce, in the matter noted in the experiments, from two to four ounces of denatured alcohol (depending upon the size of the cylinders) into each cylinder of an engine, at intervals of about three days, in order to keep the cylinders freed from carbon deposits.

Burning Out Carbon with Oxygen.—A process of recent development that gives very good results in removing carbon without disassembling the motor depends on the process of burning out that material by supplying oxygen to support the combustion and to make it energetic. A number of concerns are already offering apparatus to accomplish this work, and in fact any garage using an autogenous welding outfit may use the oxygen tank and reducing valve in connection with a simple special torch for burning the carbon. Results have demonstrated that there is little danger of damaging the motor parts, and that the cost of oxygen and labor is much lower than the old method of removing the cylinders and scraping the carbon out, as well as

being very much quicker than the alternative process of using carbon solvent. The only drawback to this system is that there is no absolute insurance that every particle of carbon will be removed, as small protruding particles may be left at points that the flame does not reach and cause pre-ignition and consequent pounding, even after the oxygen treatment. It is generally known that carbon will burn in the presence of oxygen, which supports combustion of all materials, and this process takes advantage of this fact and causes the gas to be injected into the combustion chamber over a flame obtained by a match or wax taper.

It is suggested by those favoring this process that the night before the oxygen is to be used that the engine be given a conventional kerosene treatment. A half tumbler full of this liquid or of denatured alcohol is to be poured into each cylinder and permitted to remain there over night. As a precaution against fire, the gasoline is shut off from the carburetor before the torch is inserted in the cylinder and the motor started so the gasoline in the pipe and carburetor float chamber will be consumed. Work is done on one cylinder at a time. A note of caution was recently sounded by a prominent spark plug manufacturer recommending that the igniter member be removed from the cylinder in order not to injure it by the heat developed. The outfits on the market consist of a special torch having a trigger controlled valve and a length of flexible tubing such as shown at Fig. 107, A, and a regulating valve and oxygen tank as shown at B. The gauge should be made to register about twelve pounds pressure.

The method of operation is very simple and is outlined at C. The burner tube is placed in the cylinder and the trigger valve is opened and the oxygen permitted to circulate in the combustion chamber. A lighted match or wax taper is dropped in the chamber and the injector tube is moved around as much as possible so as to cover a large area. The carbon takes fire and burns briskly in the presence of the oxygen. The combustion of the carbon is accompanied by sparks and sometimes by flame if the deposit is of an oily nature. Once the carbon begins to burn the combustion continues without interruption as long as the oxygen flows into the cylinder. Full instructions accompany each outfit and the

amount of pressure for which the regulator should be set depends upon the design of the torch and the amount of oxygen contained in the storage tank.

How Oxygen Is Produced.—While the best results are obtained by the use of the proper burner and compressed oxygen tank, it is possible to generate oxygen by very simple mechanism, and for the ingenious repairman to extemporize a burner that will give fairly good results in removing the carbon. The simplest method of producing oxygen is by heating a mixture of potassium chlorate and manganese dioxide. Although oxygen may be produced by heating potassium chlorate alone, the combination of the manganese dioxide acts as a stimulating agent which not only gives out oxygen, but which assists in breaking up the chlorate so that more of the gas will be evolved. At Fig. 108, A, an extremely simple oxygen generator that can be made by any repairman is outlined. The basis of the device consists of a 5 or 6-inch length of seamless iron pipe, one and one-half or two inches in diameter. The pipe is threaded at each end and standard pipe caps are fitted, one of these being drilled and tapped to receive a one-eighth inch brass pipe. This is bent in the form of an ell and a piece of flexible copper tubing is soldered into the end of the pipe. In order to operate this generator the unperforated cap is unscrewed and a mixture composed of two ounces of potassium chlorate and one tablespoonful of manganese dioxide is placed in the pipe. The cap is screwed back in position and the flame of a blow torch is used to heat the bottom of the iron pipe. In a short period oxygen gas will issue from the end of the copper tube joined to the generator by rubber hose, which should be placed inside of the combustion chamber against the carbonized area. A lighted match or taper thrown into the cylinder will start combustion of the carbon.

One of the latest forms of oxygen generator is shown at Fig. 108, B. The feature is that the oxygen is evolved by heating a special cartridge by an alcohol burner. The oxygen gas passes through a purifier which is provided with a safety valve to prevent accumulation of excess pressure. The purifier is connected with the oxygen generating chamber by a one-way check valve which

permits the gas to flow into the purifier, but not from that member into the generating chamber. The cartridges or charges weigh six pounds and sell for one dollar apiece. A cupful of water is placed on top of the cartridge to prevent the solder on that member from melting. When the flame plays on the bottom of the cartridge, which also acts as a generating chamber, the oxygen issues from the hole in the center into the purifying chamber.

Repairing Scored Cylinders.—If the engine has been run at any time without adequate lubrication, one or more of the cylinders may be found to have vertical scratches running up and down the cylinder walls. The depth of these will vary according to the amount of time the cylinder was without lubrication, and if the grooves are very deep the only remedy is to purchase a new member. Of course, if sufficient stock is available in the cylinder walls, the cylinders may be rebored and new pistons which are oversize, i.e., larger than standard, may be fitted. Where the scratches are not deep they may be ground out with a high speed emery wheel or lapped out if that type of machine is not available. Wrist pins have been known to come loose, especially when these are retained by set screws that are not properly locked, and as wrist pins are usually of hardened steel it will be evident that the sharp edge of that member can act as a cutting tool and make a pronounced groove in the cylinder. Cylinders that have been damaged in this manner have sometimes been repaired by the autogenous welding process, the oxy-acetylene flame being used to fuse new cast iron into the groove, then grinding out the ridge of excess material in order to obtain a smooth bore. Cylinder grinding is a job that requires skilled mechanics, but may be accomplished on any lathe fitted with an internal grinding attachment.

When a car that has been used for a considerable length of time is overhauled it may be found that the cylinder bore will have worn enough so reboring will be necessary. The wear is commonly found about midway the length of the cylinder walls, as it is at this point that the connecting rod side thrust is greatest due to the angularity of that member. In order to remedy this defective condition some repairmen are content with merely fit-

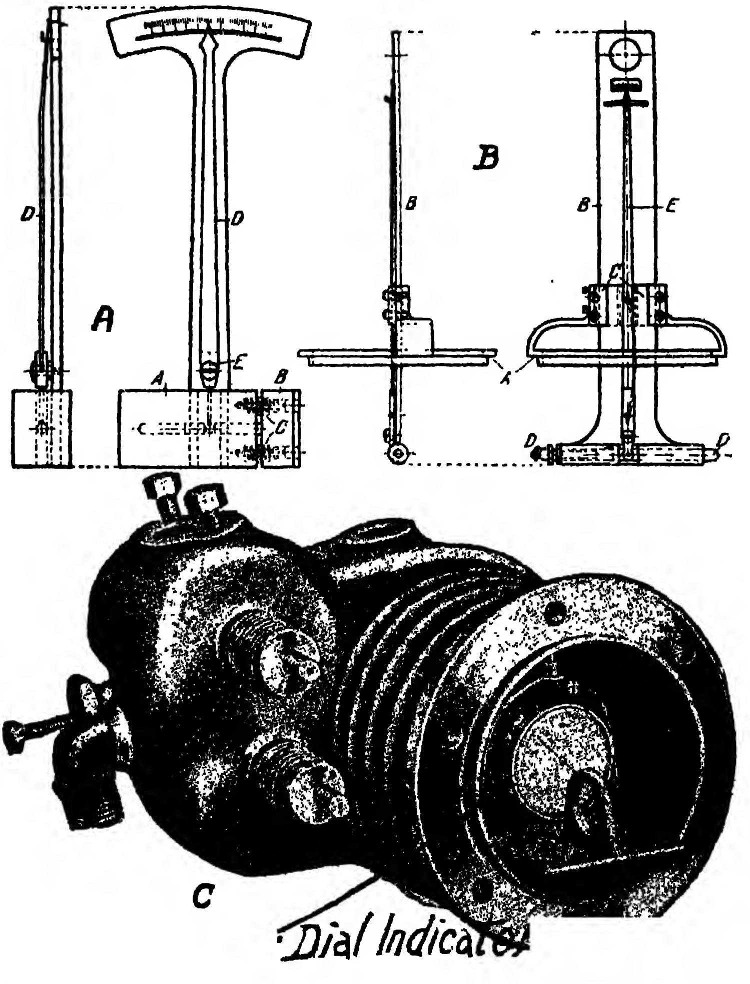


Fig. 109.—Appliances for Measuring Cylinder Bore to Determine Amount of Wear.

ting new piston rings of slightly larger circumference, but this plan is not wholly satisfactory, because if the rings are of sufficiently small diameter to enter the unworn portion of the bore, when they spring out into the worn part there must exist too wide a gap at the slots. For this reason most mechanics prefer

to fit either a new cylinder and piston or to rebore the cylinder and fit a larger piston with correspondingly larger rings.

If the car is an old one and it is not considered wise to spend the money necessary to restore the cylinder bore to correct shape, one can get considerably more service by a simple expedient of making new piston rings with long stepped ends. In this case they will pass the smaller portions of the bore and expand sufficiently to fill the worn parts. As there is no gap between the ends, even when fully expanded, there will be but little loss of compression, such as might be possible with either butt joint or diagonal cut rings under the same conditions. One precaution is essential, however, and that is to insure that the grooves are of sufficient width to take step cut rings having substantial steps. If the piston rings are narrow, the ends are apt to snap off at the steps. If the grooves are turned out to a greater width, new piston rings must be made to fit. The compression is much improved and power is increased as the rings with the long stepped joint will follow the worn bore, constricting as the bore is smaller and filling out as the wear increases.

It is not difficult to measure the bore to find out if the walls are worn. Different calipers have been devised for this purpose, some of which are illustrated at Fig. 109. These are usually constructed on the multiplying gauge principle so that the slightest inaccuracy will be magnified at the dial. In the device shown at A, a fixed block, A, carries a standard on which is fulcrumed the indicating needle, D. This indicating needle is in contact below the fulcrum with a plunger pin attached to the movable block D, which is normally kept pressed out by the coil spring C. If any irregularities are present the block B indicates them by its movement, which is translated to the short arm of the indicating lever D, which is fulcrumed at E. Another form of indicator working on practically the same principle except that the indicating lever E is actuated by the plungers DD, is shown at B. The use of the Ames Dial Indicator, carried by a special fixture for use in determining the truth of bore of automobile cylinders, is so clearly shown at Fig. 109 that it will not be necessary to mention the principle of operation any further than to state that the internal

mechanism of the indicator is such that the needle will indicate variations of less than .001 inch.

Where the grooves in the cylinder are not deep or where it has warped enough so the rings do not bear equally at all parts of the cylinder bore, it is possible to obtain a fairly accurate degree of finish by a lapping process in which an old piston is coated with a mixture of fine emery and oil and is reciprocated up and down in the cylinder as well as turned at the same time. This may be easily done by using a dummy connecting rod having only a wrist pin end boss, and of such size at the other end so that it can be held in the chuck of a drill press. The cylinder casting is firmly clamped on the drill press table by suitable clamping blocks, and a wooden block is placed in the combustion chamber to provide a stop for the piston at its lower extreme position. The back gears are put in and the drill chuck is revolved slowly. All the while that the piston is turning the drill chuck should be raised up and down by the hand feed lever, as the best results are obtained when the lapping member is given a combination of rotary and reciprocating motion.

Even if power is not available, the repairman need not be discouraged, because very good results may be obtained by hand lapping. The same method is used as for lapping by power. The abrasive material is composed of very fine emery and light machine oil, and is renewed from time to time and the cylinder cleaned out to remove the old lapping compound before any new mixture is introduced. A cylinder may be easily supported in a box of sand, as indicated, the compression relief petcock in the top of the cylinder being provided with a piece of rubber hose which projects above the surface of the same, and which acts as a breather opening for escape of the air compressed by the downward stroke of the lap.

Where the cylinders are cast in block, as is now common practice on nearly all automobiles of recent development, it is not difficult to hold the cylinder block, as this is of sufficient size and weight to stand upright on the bench without clamping it down. While the writer has used this method in repair work over ten years ago, he wishes to acknowledge his indebtedness to Motor Age

for the clear illustrations used. The process of lapping is continued until the entire interior of the cylinder is bright and clean and the scratches practically removed. All abrasive material is then washed out of the cylinder with gasoline and the walls wiped dry with a soft cloth.

How to Repair Cracked Water Jacket.—The water jacket of a gas engine cylinder will sometimes become cracked due to freez-

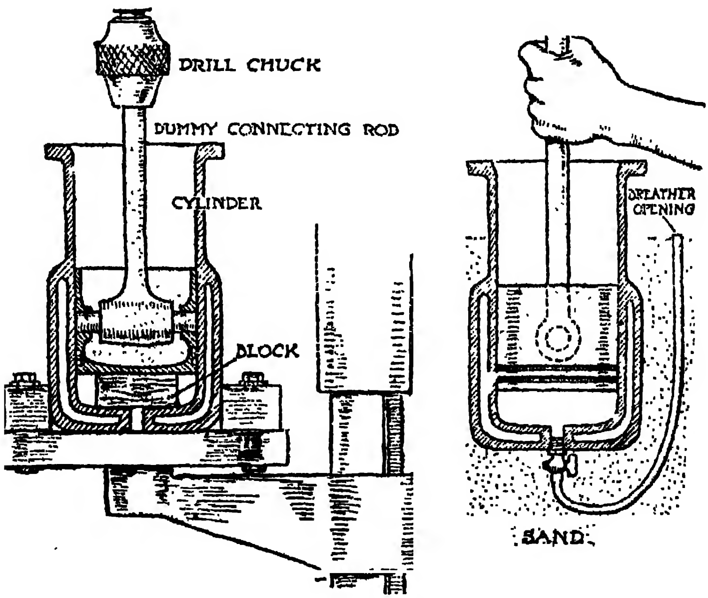


Fig. 110.—Outlining Use of Dummy Piston and Connecting Rod for Lapping Out Fine Scratches in Cylinder Bore.

ing of the cooling water, or perhaps as a result of a sand or blow hole which opens up from vibration after the cylinder has been used awhile. At the present time the usual practice in repairing cylinders is to fill the depression or crack with iron by the autogenous welding process, although various iron cements may be used for that purpose if the fracture is not serious. A mechanical repair is always possible, i.e., a metal patch can be applied to

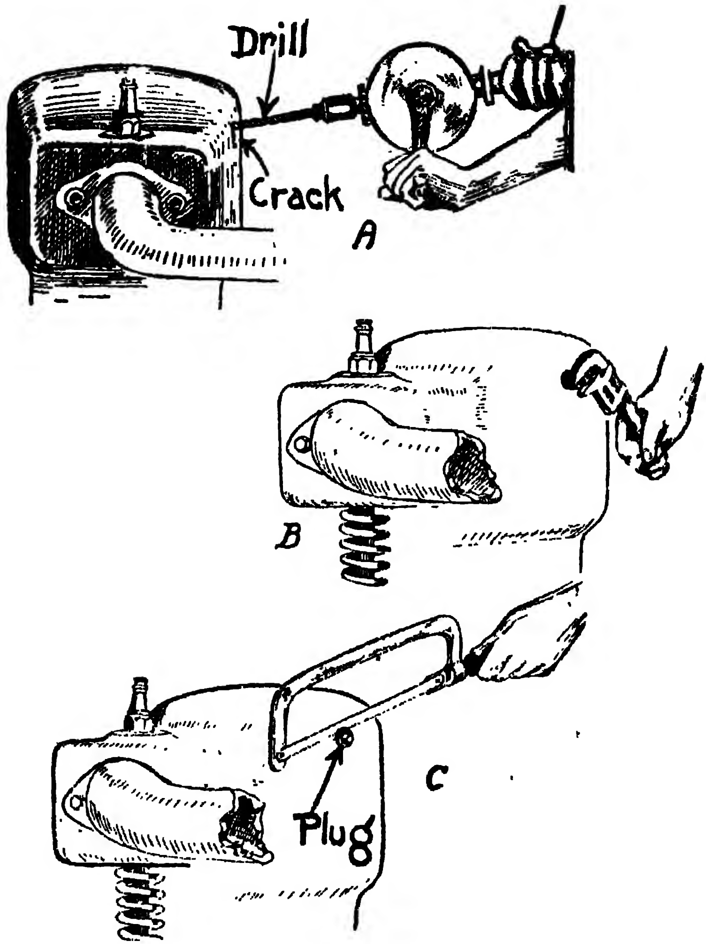


Fig. 111.—Method of Using Pipe Plug for Sealing Fine Cracks or Sand Holes in Cylinder Water Jacket.

cover the crack and held in place against a gasket interposed between the plate and the cylinder jacket by small machine screws tapped into the iron. Where only a small blow hole exists or a small crack the mechanical method shown at Fig. 111 is possible.

This consists of drilling a hole of sufficient size to take a standard pipe plug either ⅛ inch or ¼ inch, according to the size of the hole as shown at A. A pipe plug is screwed into the tapped hole as shown at D, and when it has been forced in place after coating the threads with red lead and oil or pipe joint compound to insure a tight joint, the projecting portion of the plug may be cut off with a hacksaw as outlined at Fig. 111, C, and the remaining portion of the plug filed flush with the outside of the water jacket.

If the crack is of some length it may be repaired by the following method. On the line of the fracture, drill and tap for a ⅜-inch threaded copper rod. This rod is screwed in firmly to a depth about equal to the thickness of the metal of the water jacket. Cut off the copper rod with a hacksaw, allowing it to project about 1/32 inch; then drill succeeding holes, each hole being drilled partly into the previously inserted copper plug, so that when all of the plugs are placed in the cylinder casting, they form a continuous band of copper along the line of the fracture. The copper plugs should now be peened down and trimmed off flush. The only possible chance for leakage, after having repaired the crack in this manner, is for the water to follow the joint between the metal of the jacket and the copper plugs, but as the copper rods are threaded into the casting, it is not likely to occur. Should leakage take place, a little extra peening will suffice to prevent it.

Still another method involves fusing copper filings or granulated brass spelter into the crack. This has the advantage of not requiring the removal of the part to be repaired. Drill and tap a small hole at each end of the crack to prevent further extension of the weakness, and screw in an iron stud. Next clean the outside and inside of the fracture very thoroughly, using a scraper and gasoline. File up some soft copper or brass spelter, and fill the crack, heaping the filings over it. Then take a powerful blow lamp or a torch and direct the flame on the copper. By this method a fair amount of metal can be worked into the opening. After cooling, the studs are cut off flush and the copper filed smooth. It is said that the repair will endure indefinitely.

In many cases the crack may be closed by making a rust joint.

The first step is to drill a very small hole at each end of the crack to prevent it from spreading and to drive in or screw in a metal plug in each hole. The crack is then filled up with a paste made of 66% fine iron filings or iron dust and 33% sal-ammoniac in the pulverized form, with just enough water to make a mixture of proper consistency to be forced into the crack easily. The action of the sal-ammoniac is to rapidly oxidize the fine iron filings, producing rust which joins the various iron particles together and effectively seals the opening when it has properly hardened. As a number of prepared cements for use with cast iron may be purchased at low cost, it is often cheaper to buy the cement than to attempt to make it.

A correspondent to Machinery describes still another cement of somewhat different composition than that used with success by the writer. This is composed as follows: powdered cast iron, 40 parts; powdered sal-ammoniac, 1 part; powdered sulphur, ½ part. These ingredients are thoroughly mixed together, and placed in an air-tight receptacle in a perfectly dry condition until wanted. When a hole in a casting is to be filled, take what appears to be the required quantity of the mixed powder, moisten it with water, to the consistency of paste or putty, and fill the hole or depression, smoothing it up and allowing it to set.

When very deep depressions are to be filled, add to the above mixture an equal weight of fresh "vulcanite" Portland cement before dampening. After the water has been added, so that the mixture has the desired consistency, add non-volatile oil to the extent of 8 per cent. by weight of the dry mixture used, and work the mass until the oil is fully emulsified; then apply the paste, finishing with a facing of the original mixture containing no Portland cement. This will produce a filler which will not shrink in setting.

Another method sometimes employed is to clean out the interior of the water jacket thoroughly and put in a solution of sulphate of copper or blue stone, allowing this to leak through the crack if it will. Care is taken to remove any traces of grease that may remain in the crack; this may be washed out by a boiling hot solution of potash or soda. As the copper sulphate solution leaks out, it

deposits a thin copper film, and if the crack is such that it permits only a slow leak, the defective point will be sealed overnight with a deposit of pure copper.

Inspecting Cylinder Head Packings.—On a number of overhead valve type motors having the valves carried in a removable cage gaskets are used to obtain a tight joint when the cage is screwed down. This packing frequently becomes soft, resulting in a leak around the valve. In multiple cylinder motors the gaskets that are used at the point where the intake manifold joins the respective cylinders should be examined when the manifold is removed to make sure that these are in good condition. The gasket at the exhaust pipe should also be inspected. The packings for the inlet pipe may be of well shellacked cardboard, mobiline or other asbestos packing, or even sheet rubber, but those used on exhaust pipes should only be made of asbestos or copper-asbestos. A defective gasket on the inlet manifold will seriously attenuate the mixture going to all cylinders, while a defective packing under the exhaust manifold joints will have no effect upon the operation of the motor, the only result being a sharp hiss or whistling sound due to the leaky gas.

Engines of the detachable head form have packings that are made of a sheet of asbestos sandwiched between very thin sheets of copper. While these packings have the advantage of not depreciating rapidly, at the same time they may be packed down so solid and be so stiff that they will not allow the cylinder head to bed properly after they have been used for a time. As the packings for the popular cars using them may be purchased at low cost, it is well for the repairman to always have a supply of these on hand to fit the various cars he may undertake to repair. Some cylinders, especially of the individual casting form, have a hole at the top which is used for holding the core during the casting. This hole is usually filled with a plug tightly screwed into it, and the orifice should be tightly sealed against internal pressure or water leakage. These plugs are sometimes made of bronze, and it is not unusual to find that they will leak slightly as they have become loose due to the difference in ratios of the expansion between the iron used for the cylinder and the metal of which the

plug is composed. If the cylinder is of this pattern, this plug should be looked over carefully

It sometimes happens that the retaining flange at the base of the cylinder may be cracked or a corner broken off. While the preferred method of repair is to weld it in place with the oxy-acetylene torch, an emergency repair that will prove very satisfac-

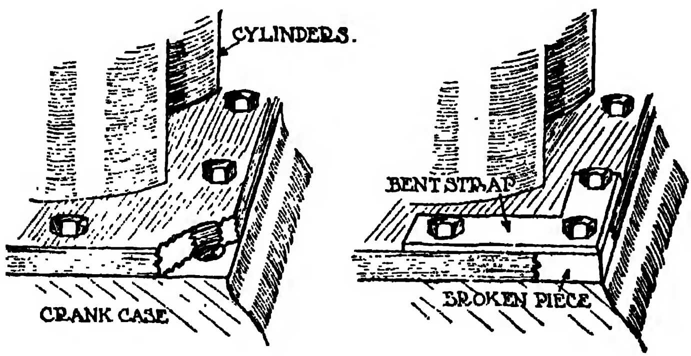


Fig. 112.—Repairing Broken Cylinder Base Flange.

tory may be made as indicated at Fig. 112. This involves the use of a bent metal strap to hold the piece in place as indicated. While this broken piece does not assist in retaining the cylinder in place on the crankcase, it serves the useful purpose of keeping dirt and grit from entering the crankcase. The strap assists in holding the cylinder, however.

A number of cylinder designs, especially those in which four or more cylinders are cast in a block, have a large plate at the side which is used to close the water jacket, this forming a cover for an opening which had been left to facilitate foundry work when the cylinder was cast. This plate is either of sheet brass or aluminum; in some cases it may be an aluminum casting having a portion of the intake manifold cast with it. Leakage is prevented by a packing interposed between the plate and the cylinder,

the plate being firmly secured to the water jacket by a number of closely spaced machine screws. This is a common method of construction and one often finds water leaks about the plate on inspection. The packing used is a rubber and fabric composition of the form known by the trade name "Rainbow" steam packing. This may be easily cut to proper size and holes punched in with a belt punch to allow the screws to pass through. In some instances simply removing the plate and smearing the gasket with shellac or red lead and then replacing the plate, taking care to screw down all the screws tightly, will cure the leak. One advantage of this plate is that it may be easily removed to permit the repairman to clean out the water jacket thoroughly of any accumulation of rust or sediment which may have become deposited there and which will interfere with proper cooling. On some forms of cylinders, applied copper water jackets are used, and a slight leak may be manifested at the lower joint. This may be stopped in most cases by just peening in the retention or clamping ring, soldering or by calking with lead.

Valve Removal and Inspection.—One of the most important parts of the gasoline engine and one that requires frequent inspection and refitting to keep in condition is the mushroom or poppet valve that controls the inlet and exhaust gas flow. In overhauling it is essential that these valves be removed from their seatings and examined carefully for various defects which will be enumerated at proper time. The problem that concerns us now is the best method of removing the valve. These are held against the seating in the cylinder by a coil spring which exerts its pressure on the cylinder casting at the upper end and against a suitable collar held by a key at the lower end of the valve stem. In order to remove the valve it is necessary to first compress the spring by raising the collar and pulling the retaining key out of the valve stem. Many forms of valve spring lifters have been designed to permit ready removal of the valves. The most common forms that have received application in practice are shown at Figs. 113 and 114. The form shown at Fig. 113, A, is composed of two levers hinged together in such a way that squeezing the handles together will spread the other ends instead of closing them

as is the case with pliers. One end of the tool is rested on a valve lift plunger, the other end bears against the valve spring collar, as indicated. When the handles are pressed together the valve spring collar is raised, this compressing the spring and permitting removal of the retaining key. A ratchet lock is provided to keep the handles closed so that both hands may be used in lifting the key out of the valve stem, if necessary. The form outlined at B consists of a hinge or supporting member and a lever carrying a fork at one end to engage the valve spring collar. The fulcrum member is carried by an adjustable support into which it is threaded. The supporting piece may be moved up or down on the fulcrum bolt, this adapting the tool for various forms and sizes of valves. The device outlined at C consists of a frame having a slotted bearing for the spring lifting bell crank supporting bolt, making it possible to move that member up or down to adapt the tool for different spaces between the valve spring collar and the valve operating push rod. The bell crank is lifted by a screw which makes it possible to compress the heaviest valve spring without trouble.

One objection against either of the forms of valve spring lifters shown at A, B and C is that some means must be provided to prevent the valve head from coming off its seat. This is usually done by interposing a small block of wood between the valve head and the valve chamber cap or by holding the valve head against the seat with a screw-driver or other tool. The valve spring lifter shown at D has the important advantage of keeping the valve head firmly pressed against the seat at the same time that the valve spring cap or collar is lifted. This consists of a cast forked lever of peculiar shape provided with notches to engage a jack chain. One end of the jack chain is attached to a hook which is intended to bear down against the valve head. Another form in which the hook principle is carried out is shown at E. This consists of a frame bar having a series of holes at its lower end designed to fit the fulcrum pin of the valve spring lifting lever.

Another application of the screw form of valve spring lifter is shown at F. This consists of a main portion or frame bar having the upper end threaded to fit the T-handle screw while the

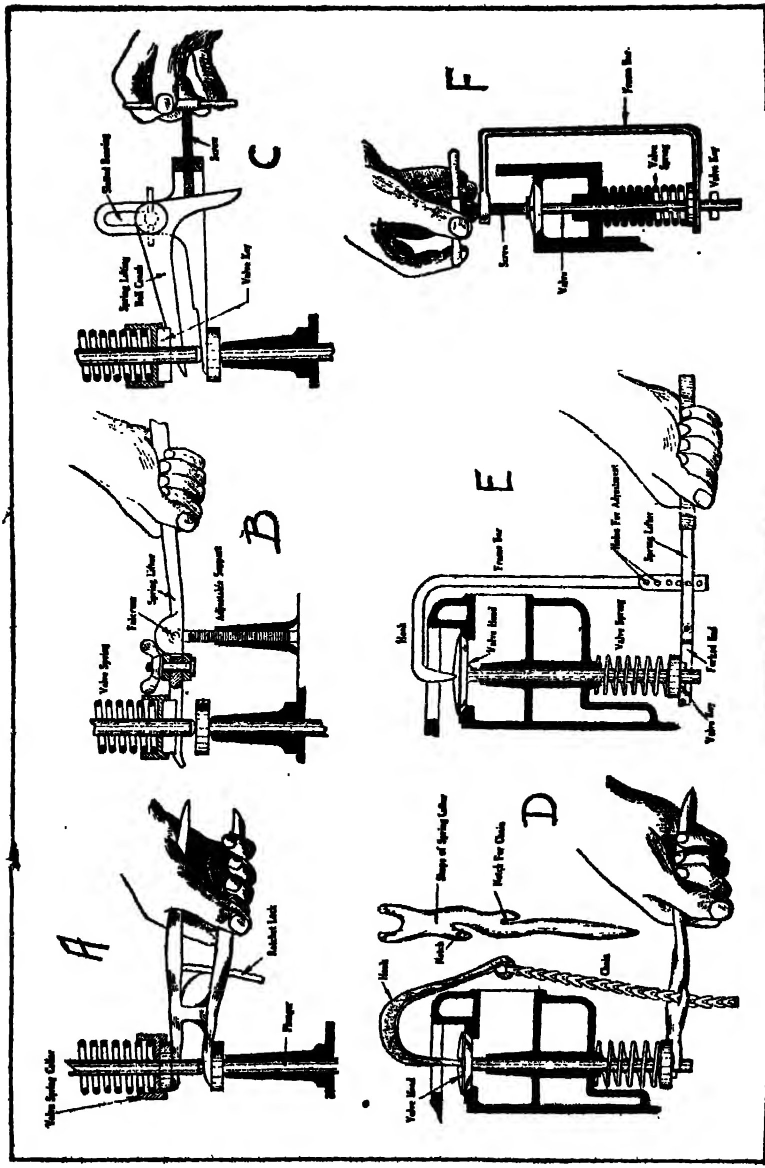


Fig. 113.—Application of Valve Spring Compressing Tool to Permit Removal of Valve Stem Keys.

lower end is in the form of a yoke to straddle the valve stem and lift the valve spring collar. This is a very efficient form and has the advantage of keeping the spring compressed as long as desired, permitting ready removal of the valve key, which is an advantage not possessed by the lever form in which one hand must be used at the lever end while the other is depended on to remove the key. With the valve spring lifter shown at A, C and F, both hands may be used for the work, as the devices will keep the spring compressed as long as desired. The construction is so clearly shown that any one of the valve spring lifters outlined may be readily duplicated by the repairman at slight expense.

An ingenious method of keeping a valve spring compressed while the key is extracted from the stem is shown at Fig. 114, A. A piece of iron pipe is cut of such length that two pieces may be obtained by cutting the pipe longitudinally in half. The longest of these pieces is of such height as is necessary to raise the valve spring collar sufficiently high to free it entirely from the key. The other piece is shorter. In operation the valve lift plunger is raised by its cam as shown at A 1. This permits one to introduce the short piece of pipe between the crankcase and the valve spring collar. The camshaft is then rotated until the plunger returns to the lower end of its stroke again. A wide space then exists between the end of the valve stem and the top of the plunger. A piece equal to the difference in height between the short pipe shown at A 1 and the long piece of pipe shown at A 3 is then inserted to fill this space between the valve stem and plunger. The camshaft is again rocked or turned sufficiently so the cam again raises the valve plunger. This brings the valve spring collar still higher and permits one to insert the long piece of pipe as at A 3. When the valve head is pushed down on its seat the key is readily accessible, and may be easily removed with a small pair of pliers.

The special valve spring lifter furnished for Ford repairmen has been previously outlined. The method of using it is shown at Fig, 114, B. The construction of a simple valve spring lifter that can be used on two valves at a time is shown at C. This consists of a forked casting adapted to bear on the valve plunger guide tops and carrying a steel stud at its center. The member designed

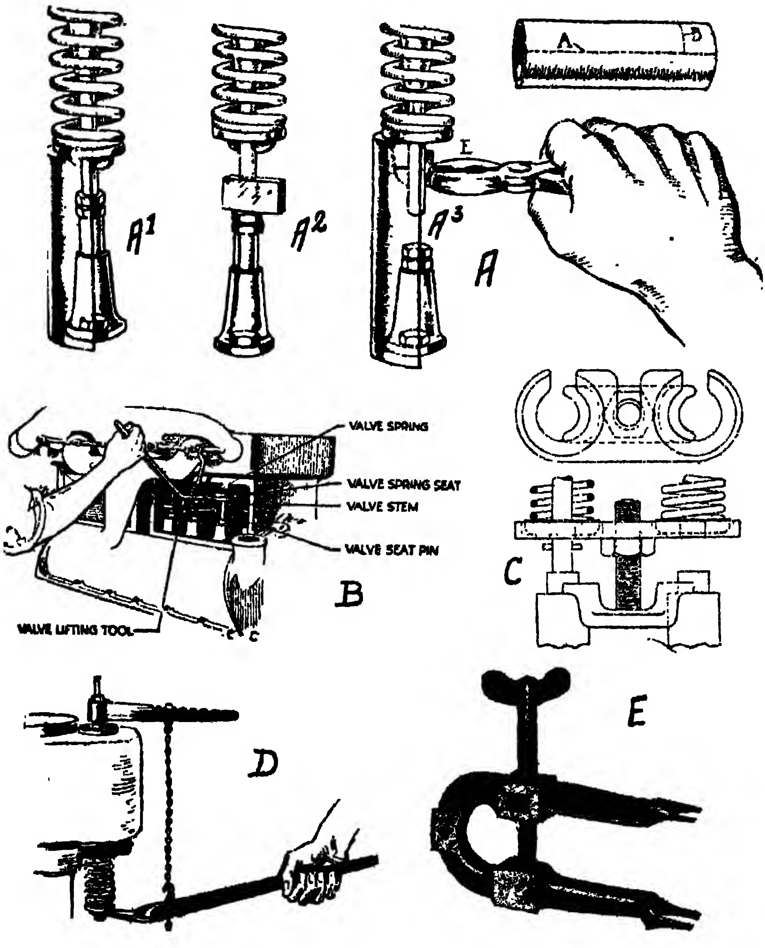


Fig. 114.—Valve Spring Lifting Tools of Varied Design.

to engage the valve spring collar is also a casting of such form as indicated in the plan view at C. This has three slots making it possible to insert it easily between the valve spring collar and the pin passing through the valve stem. If one screws up on the lifting nut, it is apparent that the valve spring will be compressed

and the pins passing through the valve stem may be easily removed. This device is especially adapted for use on Ford motors. The Winsor valve spring lifter shown at D is a modification of the form shown at Fig. 113, E. The arm on which the supporting chain is hooked is carried by a bolt adapted to screw into the spark plug hole in the valve chamber cap. This carries a bolt through its center which may be screwed down to hold the valve head securely against the seat. Under these conditions it is not difficult to raise the valve spring collar with the lever provided for the purpose and extract the spring retaining key or pin. A double forked form of valve spring lifter known as the "Universal" is shown at Fig. 114, E. This works on the same principle as that shown at Fig. 113, A, a screw being used to spread the ends which are forked to fit around the valve stem and the valve lift plunger respectively.

When the cylinder is of the valve in-the-head form, the method of valve removal will depend entirely upon the system of cylinder construction followed. In the Knox cylinder shown at Fig. 103 it is possible to remove the head from the individual cylinder castings and the valve springs may be easily compressed by any suitable means when the cylinder head is placed on the work bench where it can be easily worked on. The usual method is to place the head on a soft cloth with the valves bearing against the bench. The valve springs may then be easily pushed down with a simple forked lever and the valve stem key removed to release the valve spring collar. In the Franklin engine, which is shown in part section at Fig. 115, it is not possible to remove the valves without taking the cylinder off the crank case, because the valve seats are machined directly in the cylinder head and the valve domes are cast integrally with the cylinder. This means that if the valves need grinding the cylinder must be removed from the engine base to provide access to the valve heads which are inside of that member, and which cannot be reached from the outside as is true of the L- or T-cylinder construction.

The preferred method of carrying the valves when they are placed in the cylinder head is shown at Fig. 116, which is a part sectional view of the Buick 6-cylinder motor. The valves are car-

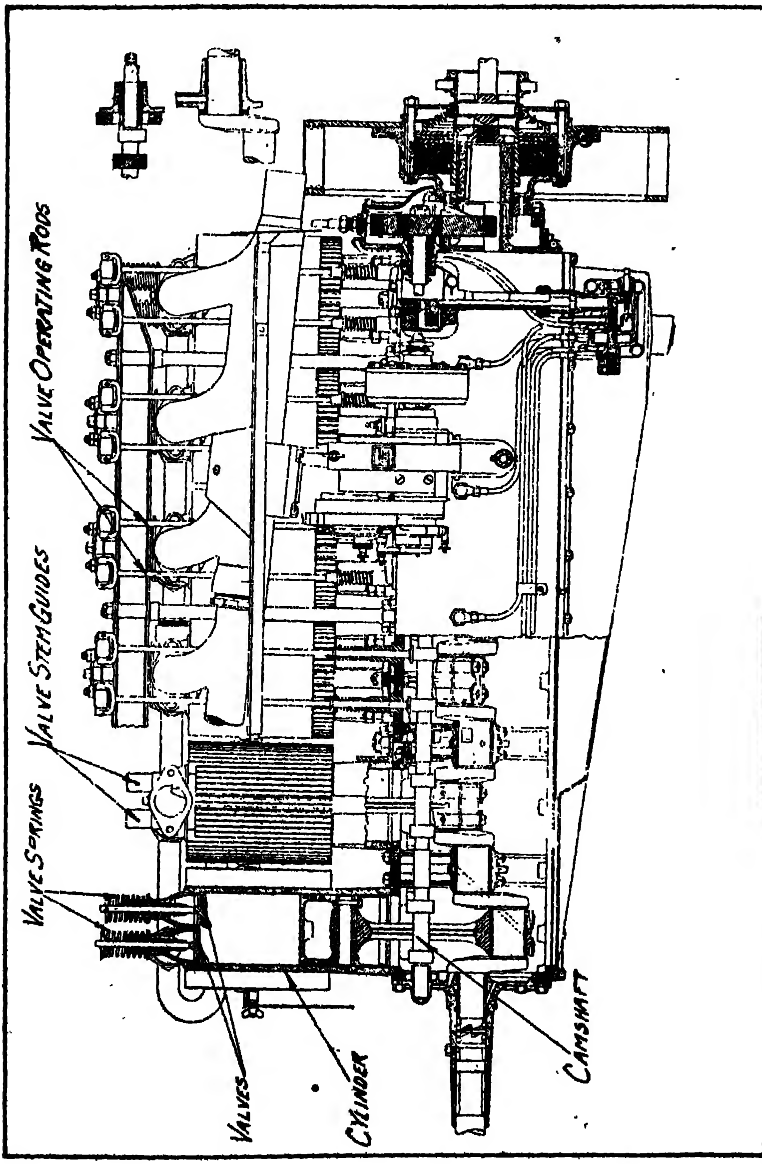


Fig. 115.—Part Sectional View of the Franklin Six Cylinder Air Cooled Engine, Showing Unconventional Valve Installation.

ried in cages which are readily removed from the cylinder head by unscrewing the retention nut that keeps the valve cage tightly pressed against the seating at its lower end to obtain a gas-tight joint. The valve cages are easy to handle and it is a relatively simple operation to compress the valve spring and remove the pin which makes for easy removal of the valve. When this construction is followed it is possible to grind in the valve by simply removing the cage assemblies from the cylinder. It is not necessary to disturb the cylinder in any way and does not call for disconnection of intake or exhaust manifolds; the only things that need be removed are the valve operating tappets, which is work of but a few moments.

The detachable head idea has been carried out in a distinctive manner on the Premier-Weidely motor, which is shown in part section at A, Fig. 117. In this the valves seat directly into the cylinder head member which serves six cylinders. This construction is made possible by casting the six cylinders in a block and using the type of cylinder head packing made popular by the Ford car. The valves are operated by an overhead camshaft which depresses the valve stems through the medium of a cam rider which relieves the valve stem of the side thrust which would be present if the cam worked directly against the end of the valve stem. In order to remove the valve with this construction it is necessary to dismount the camshaft and cam riders which are shown at B, in order to expose the valve spring collars as indicated at D. The entire cylinder head may be tilted up on the bench as shown at C, which gives ready access to the valves which are provided with a slotted boss making it possible to turn them with a screw-driver bit when grinding them to a correct seating. It is evident that the valves cannot be worked on without removing the cylinder head from the cylinder block casting.

Reseating and Truing Valves.—Much has been said relative to valve grinding, and despite the mass of information given in the trade prints it is rather amusing to watch the average repairman or the motorist who prides himself on maintaining his own car performing this essential operation. The common mistakes are attempting to seat a badly grooved or pitted valve head on an

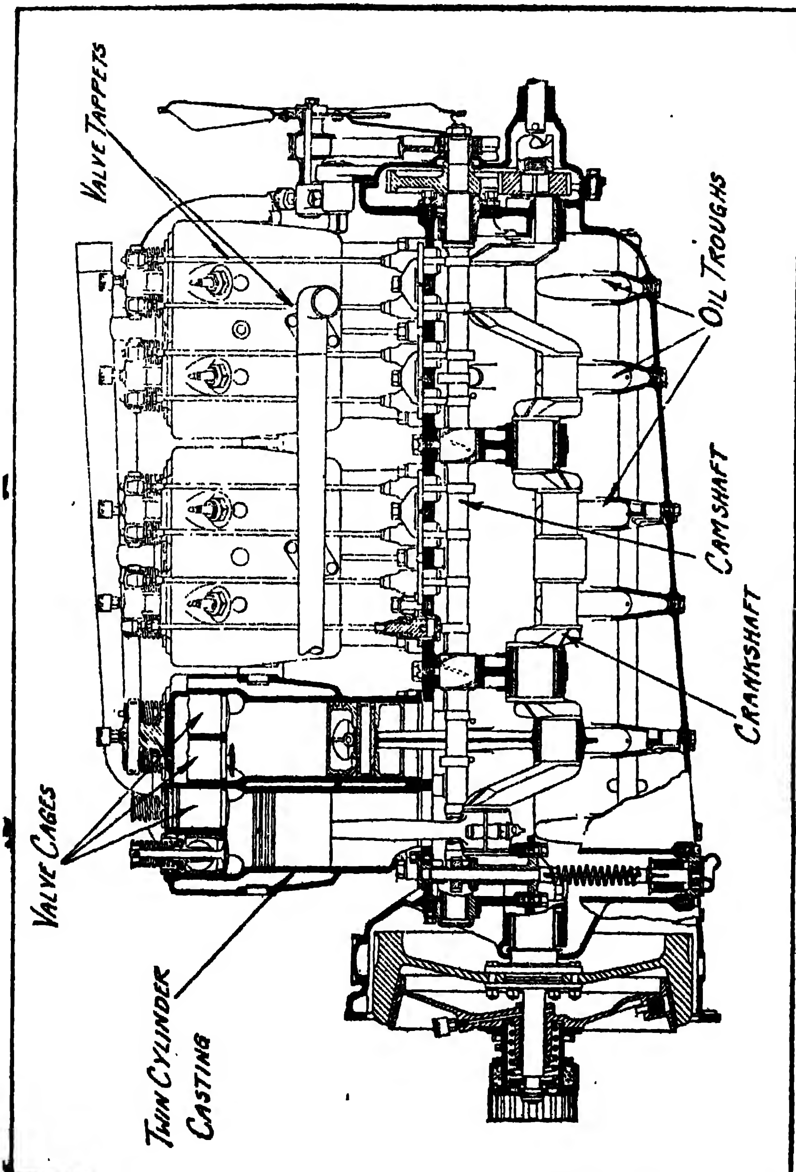


Fig. 116.—Part Sectional View of Six Cylinder Buick Motor, Showing Method of Valve Mounting in Easily

equally bad seat, which is an almost hopeless job, and of using coarse emery and bearing down with all one's weight on the grinding tool with the hope of quickly wearing away the rough surfaces. The use of improper abrasive material is a fertile cause of failure to obtain a satisfactory seating. Valve grinding is not a difficult operation if certain precautions are taken before undertaking the work. The most important of these is to ascertain

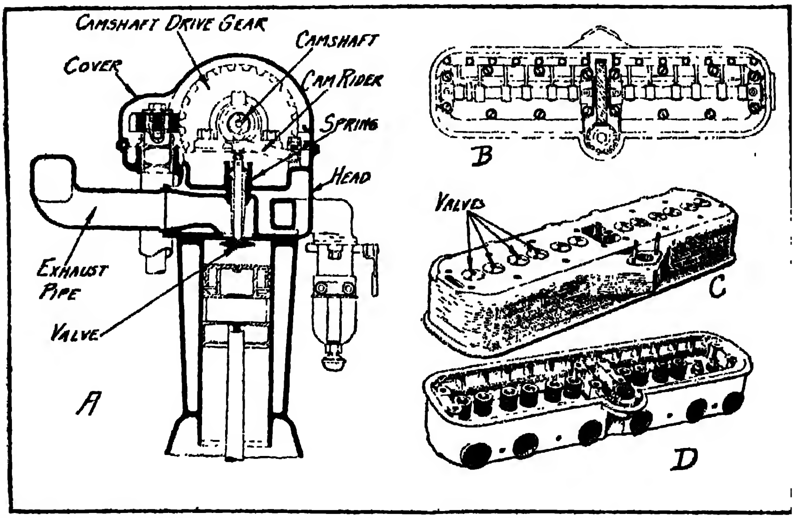


Fig. 117.—Sectional View Showing Construction of Premier-Weidely Overhead Valve, Detachable Cylinder Head Motor.

if the valve head or seat is badly scored or pitted. If such is found to be the cause no ordinary amount of grinding will serve to restore the surfaces. In this event the best thing to do is to remove the valve from its seating and to smooth down both the valve head and the seat in the cylinder before attempt is made to fit them together by grinding. Another important precaution is to make sure that the valve stem is straight, and that the head is not warped out of shape or loose on the stem when the valve is a two-piece member.

A number of simple tools is available at the present time for

reseating valves, these being outlined at Fig. 118. That shown at A is a simple fixture for facing off the valve head. The stem is supported by suitable bearings carried by the body or shank of the tool, and the head is turned against an angularly disposed cutter which is set for the proper valve seat angle. The valve head is turned by a screw-driver, the amount of stock removed from the head depending upon the location of the adjusting screw. Care must be taken not to remove too much metal, only enough being taken off to remove the most of the roughness. Valves are made in two standard tapers, the angle being either 45 or 60 degrees. It is imperative that the cutter blade be set correctly in order that the bevel is not changed. A set of valve truing and valve-seat reaming cutters is shown at Fig. 118, B. This is adaptable to various size valve heads, as the cutter blade D may be moved to correspond to the size of the valve head being trued up. These cutter blades are made of tool steel and have a bevel at each end, one at 45 degrees, the other at 60 degrees. The valve seat reamer shown at G will take any one of the heads shown at F. It will also take any one of the guide bars shown at H. The function of the guide bars is to fit the valve stem bearing in order to locate the reamer accurately and to insure that the valve seat is machined concentrically with its normal center. Another form of valve seat reamer and a special wrench used to turn it is shown at C. The valve head truer shown at Fig. 118, D, is intended to be placed in a vise and is adaptable to a variety of valve head sizes. The smaller valves merely fit deeper in the conical depression. The cutter blade is adjustable and the valve stem is supported by a simple self-centering bearing. In operation it is intended that the valve stem, which protrudes through the lower portion of the guide bearing, shall be turned by a drill press or bit stock while the valve head is set against the cutter by pressure of a pad carried at the end of a feed screw which is supported by a hinged bridge member. This can be swung out of place as indicated to permit placing the valve head against the cutter or removing it.

As the sizes of valve heads and stems vary considerably a "Universal" valve head truing tool must have some simple means of centering the valve stem in order to insure concentric machining

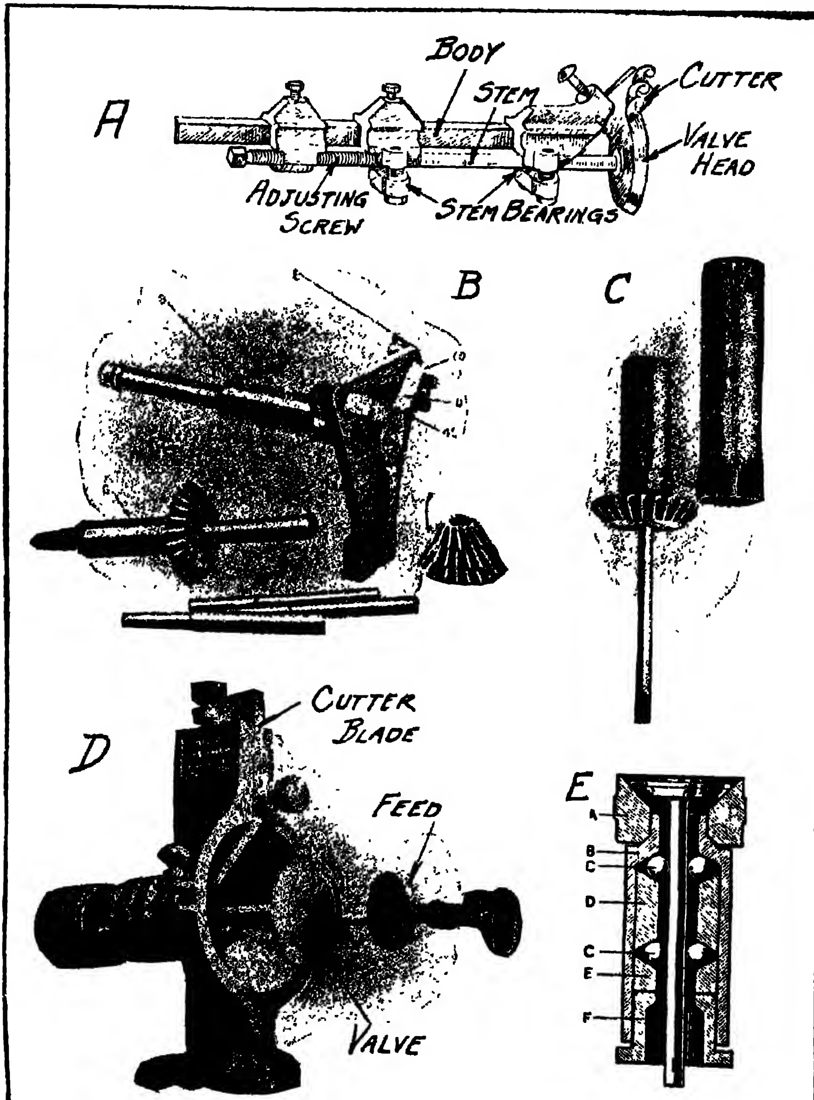


Fig. 118.—Tools for Restoring Valve Head and Seats.

of the valve head. A valve head truer which employs an ingenious method of guiding the valve stem is shown at Fig. 118, E. The device consists of a body portion B, provided with an external thread at the top on which the cutter head A, is screwed. A number of steel balls C, are carried in the grooves which may be altered in size by the adjustment nut F, which screws in the bottom of the body portion B. As the nut F is screwed in against the spacer member E, the V-grooves are reduced in size and the steel balls C are pressed out in contact with the valve stem. As the circle or annulus is filled with balls in both upper and lower portions the stem may be readily turned because it is virtually supported by ball bearing guides. When a larger valve stem is to be supported, the adjusting nut F, is screwed out which increases the size of the grooves and permits the balls C, to spread out and allow the larger stem to be inserted.

In straightening a spindle, light shaft or valve stem that has accidentally become bent, hammering the piece straight is crude and unmechanical and usually results in bruising it. A better way to straighten a bent valve stem is shown in the illustrations at Fig. 119. The part to be straightened, in this case an exhaust valve, should first be heated at the bent portion with a flame from a blow torch which is deflected against the portion to be raised to a high temperature by a simple band iron fixture to localize the flame. This is indicated at A, and the method of using it is shown at B. While the bend is still hot the valve stem is placed between the jaws of a strongly built vise as shown at C. Cut or file V-shape notches in three nuts or other pieces of metal, lay the bent piece between the jaws with one of the nuts under the bent portion and the other two spaced further apart as indicated. Apply steady pressure with the vise screw and the piece will spring back into shape. By moving the supporting blocks N from one portion of the valve stem to the other, always exerting pressure against the bent part or high spot with one of the nuts, it will be possible to straighten the stem by removing kinks at all points. While it is preferable to support the valve in lathe centers to determine when it is accurately straightened, if a lathe is not available a simple frame as shown at D, in which nails are

used as centers in upright blocks of wood may be extempo[illegible] The valve is swung around and the high portions are indic[illegible] with a piece of chalk.

The use of a clamp to straighten the valve stem is show[illegible] D-2, this being suggested for use where a vise is not ava[illegible] A stiff metal piece is laid on top of the clamp screw and tw[illegible] porting blocks are placed on it to keep the valve in place. A [illegible] of soft sheet metal such as brass or copper is interposed be[illegible]

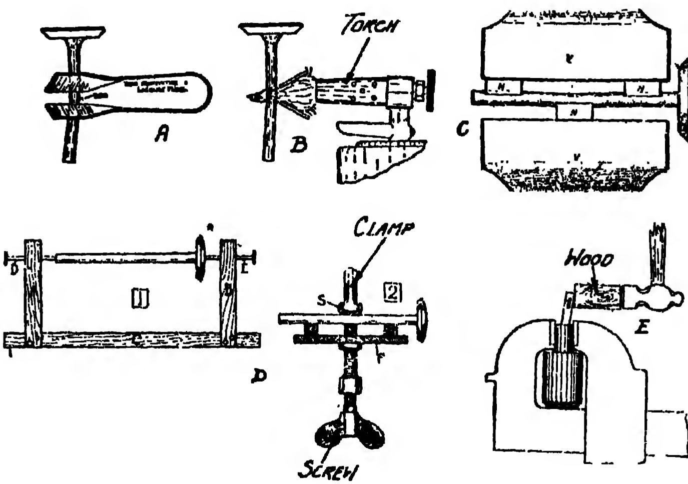


Fig. 119.—Simple Methods of Straightening Bent Valve Stems.

the fixed end of the clamp and the valve stem in order not to mar that member. The method of straightening a bent valve stem in order to permit the removal of that member when it is carrie[illegible] in a removable valve cage is shown at Fig. 119, E. If one attempts to press or drive the valve out when the stem sticks from being bent the valve stem guide is apt to be broken, becaus[illegible] is of cast iron which is a brittle material that will not stand [illegible] stresses.

In straightening the valve the vise jaws are provided with [illegible] metal cap pieces and the cast iron valve stem guide is firml[illegible]

of t ped between these members. When supported in this manner me e is no danger of breaking off the boss and the stem may de straightened by blows from the hammer, taking care to interpose thr ock of hard wood or a piece of babbitt metal between the num stem and the hammer. When the valve cage is placed in the be a are will be taken to have the bent portion of the stem at the botto the hub and it will also be important to have the valve stem the lined that the blows directed against it will be exerted along longitudinal center line of the vise. The valve stems are en bent when a wrench used to remove the cages slips and strikes the valve stem. The repairman may consider the work sufficiently well done when the stem has been so straightened that the valve will fall out of the cage of its own weight. It is evident that the hammer blows must be carefully directed and that the force of these be gauged intelligently as it is better to do the traightening with a series of light blows than with a lesser ac aber of heavy ones which may cause damage.

an **Valve Grinding Processes.**—Mention has been previously made wa the importance of truing both valve head and seat before at-at apt is made to refit the parts by grinding. The appearance of v valve head when pitted or scored is indicated at Fig. 120, A, order that the motorist or novice repairman can readily identify nis defective condition. After smoothing the valve seat the next step is to find some way of turning the valve. Valve heads are usually provided with a screw driver slot passing through the boss at the top of the valve or with two drilled holes to take a forked grinding tool. The method of arranging the valve head for the grinding tool and the types of grinding tools commonly used are also shown at Fig. 120, A. A combination grinding tool which may be used when either the two drilled holes or the slotted lead form of valve is to be rotated is shown at Fig. 120, B. This consists of a special form of screw driver having an enlarged boss just above the blade, this boss serving to support a U-shape piece it h can be securely held in operative position by the clamp at or which can be turned out of the way if the screw driver cen is to be used.

As it is desirable to turn the valve through a portion of a revo-

lution and back again rather than turning it always in the same direction, a number of special tools has been designed to make this oscillating motion possible without trouble. A simple valve grinding tool is shown at Fig. 120, C. This consists of a screw driver blade mounted in a handle in such a way that the end may turn freely in the handle. A pinion is securely fastened to the screw driver blade shank, and is adapted to fit a race provided with a wood handle and guided by a bent bearing member securely fastened to the screw driver handle. As the rack is pushed back and forth the pinion must be turned first in one direction and then in the other.

A valve grinding tool patterned largely after a breast drill is shown at Fig. 120, D. This is worked in such a manner that a continuous rotation of the operating crank will result in an oscillating movement of the chuck carrying the screw driver blade. The bevel pinions which are used to turn the chuck are normally free unless clutched to the chuck stem by the sliding sleeve which must turn with the chuck stem and which carries clutching members at each end to engage similar members on the bevel pinions and lock these to the chuck stem, one at a time. The bevel gear carries a cam piece which moves the clutch sleeve back and forth as it revolves. This means that the pinion giving forward motion of the chuck is clutched to the chuck spindle for a portion of a revolution of the gear and clutch sleeve is moved back by the cam and clutched to the pinion giving a reverse motion of the chuck during the remainder of the main drive gear revolution.

A method that can be used for smoothing the surface of a valve head when the usual form of valve head truer is not available is indicated at Fig. 120, E. The valve heads are usually provided with a small depression in the center known as a countersink which is designed to act as a support for the valve when it is being machined from the forging. The stem of the valve is caught in the chuck of a bit stock and rested on any sharp point on a wall or bench. This can be easily made by driving a large wire nail in the bench from underneath so that the point projects through the bench. The bit stock is briskly turned by a helper and the rough spots are removed from the seat with a fine file, care

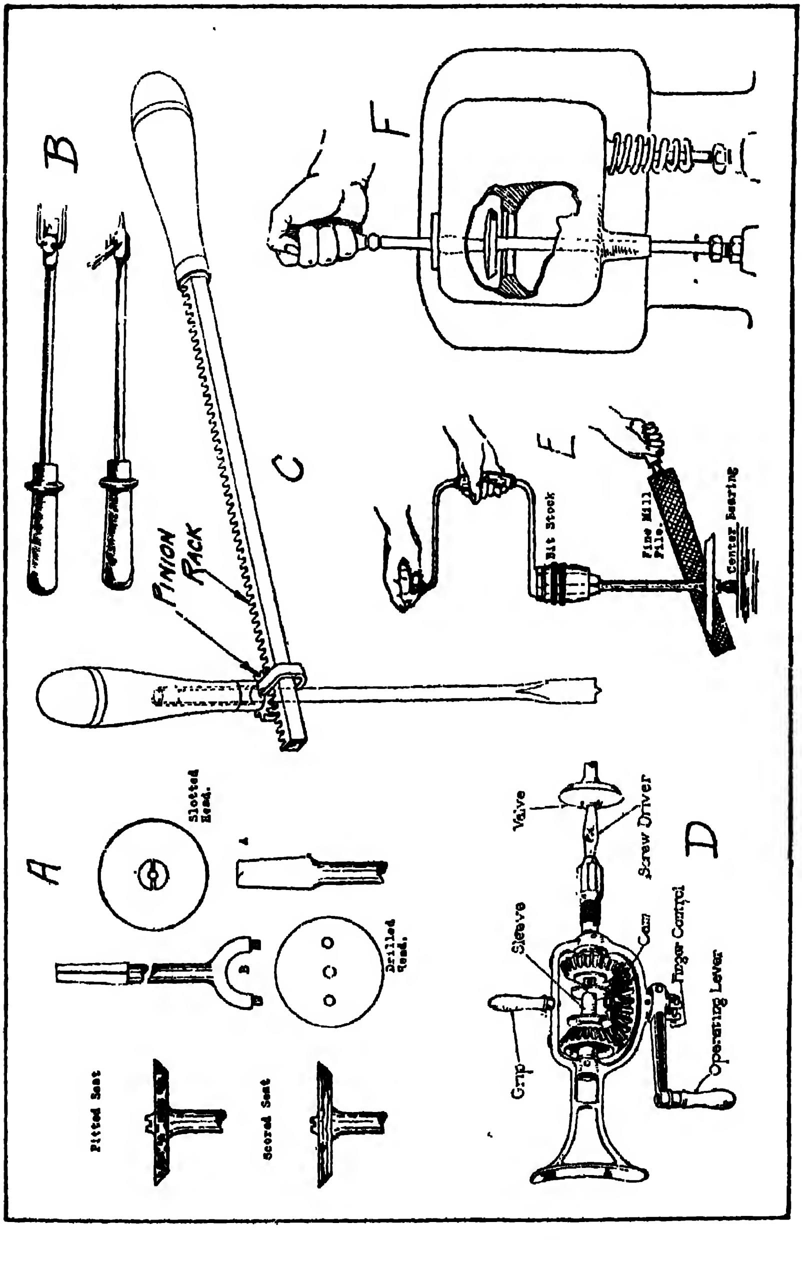


Fig. 120.—Forms of Valve Grinding Tools.

being taken not to change the taper of the valve head. The valve stem could be turned much faster and a superior finish obtained if a breast drill were used instead of a bit stock, though with care a very creditable job may be done with the latter.

One of the things to watch for in valve grinding is clearly indicated at Fig. 120, F. It sometimes happens that the adjusting screw on the valve lift plunger or the valve lift plunger itself does not permit the valve head to rest against the seat. While the condition is exaggerated in the sketch it will be apparent that unless a definite space exists between the end of the valve stem and the valve lift plunger that grinding will be of little avail because the valve head will not bear properly against the abrasive material smeared on the valve seat.

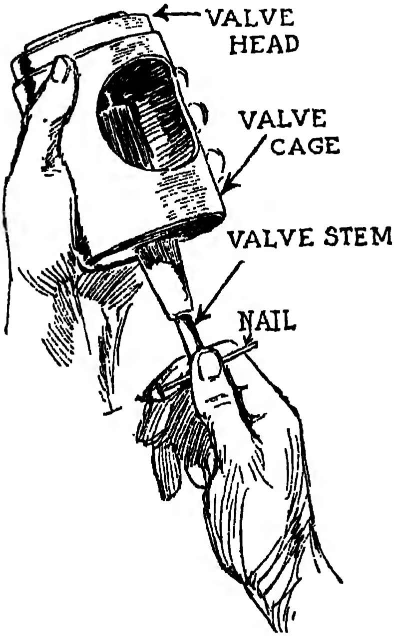
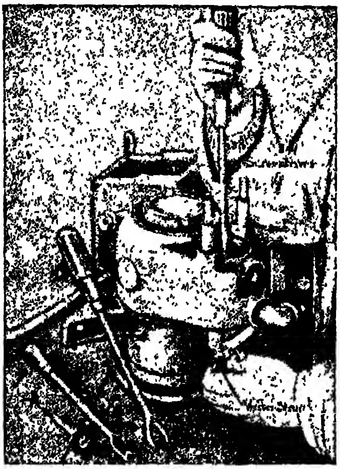


Fig. 121.—A Nail or Piece of Wire Only Tool Necessary for Grinding Buick Valves to Correct Seating in Cage.

The usual methods of valve grinding are clearly outlined at Fig. 122. The view at the left shows the method of turning the valve by an ordinary screw driver and also shows a valve head at A, having both the drilled holes and the screw driver slot for turning the member and two special forms of fork-end valve grinding tools. In the sectional view shown at the right, the use of the light spring between the valve head and the bottom of the valve chamber

to lift the valve head from the seat whenever pressure on the grinding tool is released is clearly indicated. It will be noted also that a ball of waste or cloth is interposed in the passage between the valve chamber and the cylinder interior to prevent the abrasive material from passing into the cylinder from the valve chamber. When a bitstock is used, instead of being given a true rotary



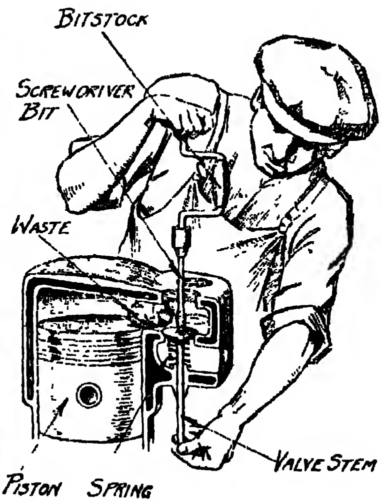


Fig. 122.—Showing Practical Methods of Valve Grinding. At Left, with Ordinary Screw Driver; at Right, with Screw Driver Bit and Bitstock.

motion the chuck is merely oscillated through the greater part of the circle and back again. It is necessary to lift the valve from its seat frequently as the grinding operation continues, this is to provide an even distribution of the abrasive material placed between the valve head and its seat. Only sufficient pressure is given to the bitstock to overcome the uplift of the spring and to insure that the valve will be held against the seat. Where the spring is not used it is possible to raise the valve from time to time with the hand which is placed under the valve stem to raise it as the grinding is carried on. It is not always possible to lift the valve

in this manner when the cylinders are in place on the engine base owing to the space between the valve lift plunger and the end of the valve stem. In this event the use of the spring as shown in sectional view will be desirable.

The abrasive generally used is a paste made of medium or fine emery and lard, oil or kerosene. This is used until the surfaces are comparatively smooth, after which the final polish or finish is given with a paste of flour emery, grindstone dust, crocus, or ground glass and oil. An erroneous impression prevails in some quarters that the valve head surface and the seating must have a mirror-like polish. While this is not necessary it is essential that the seat in the cylinder and the bevel surface of the head be smoo nd free from pits or scratches at the completion of the operatic All traces of the emery and oil should be thoroughly washed out of the valve chamber with gasoline before the valve mechanism is assembled and in fact it is advisable to remove the old grinding compound at regular intervals, wash the seat thoroughly and supply fresh material as the process is in progress. The truth of seatings may be tested by taking some Prussian blue pigment and spreading a thin film of it over the valve seat. The valve is dropped in place and is given about one-eighth turn with a little pressure on the tool. If the seating is good both valve head and seat will be covered uniformly with color. If high spots exist, the heavy deposit of color will show these while the low spots will be made evident because of the lack of pigment. The grinding process should be continued until the test shows an even bearing of the valve head at all points of the cylinder seating. When the valves are held in cages it is possible to catch the cage in a vise and to turn the valve in any of the ways indicated. It is much easier to clean off the emery and oil and there is absolutely no danger of getting the abrasive material in the cylinder if the construction is such that the valve cage or cylinder head member carrying the valve can be removed from the cylinder. When valves are held in cages, the tightness of the seat may be tested by partially filling the cage with gasoline and noticing how much liquid oozes out around the valve head. The degree of moisture present indicates the efficacy of the grinding process.

Depreciation in Valve Operating Systems.—There are a number of points to be watched in the valve operating system because valve timing may be seriously interfered with if there is much lost motion at the various bearing points in the valve lift mechanism. The two conventional methods of opening valves are shown at Fig. 123. That at A, is the type employed when the valve cages are mounted directly in the head, while the form at B, is the system used when the valves are located in a pocket or extension of the cylinder casting as is the case if an L, or T-head cylinder is used. It will be evident that there are several points where depreciation may take place. The simplest form is that shown at B, and even on this there are five points where lost motion may be noted. The periphery of the valve opening cam or roller may be worn though this is not likely unless the roller or cam has been inadvertently left soft. The pin which acts as a bearing for the roller may become worn, this occurring quite often. Looseness may materialize between the bearing surfaces of the valve lift plunger and the plunger guide casting and there may also be excessive clearance between the top of the plunger and the valve stem.

On the form shown at A, there are several parts added to those indicated at B. A walking beam or rocker lever is necessary to transform the upward motion of the tappet rod to a downward motion of the valve stem. The pin on which this member fulcrums may wear as will also the other pin acting as a hinge or bearing at the yoke end of the tappet rod. It will be apparent that if slight play existed at each of the points mentioned it might result in a serious diminution of valve opening. Suppose, for example, that there were .005-inch lost motion at each of three bearing points, the total lost motion would be .015-inch or sufficient to produce noisy action of the valve mechanism. When valve plungers of the adjustable form, such as shown at B, are used, the hardened bolt head in contact with the end of the valve stem may become hollowed out on account of the hammering action at that point. It is imperative that the top of this member be ground off true and the clearance between the valve stem and plunger properly adjusted. If the plunger is a non-adjustable type it will be necessary

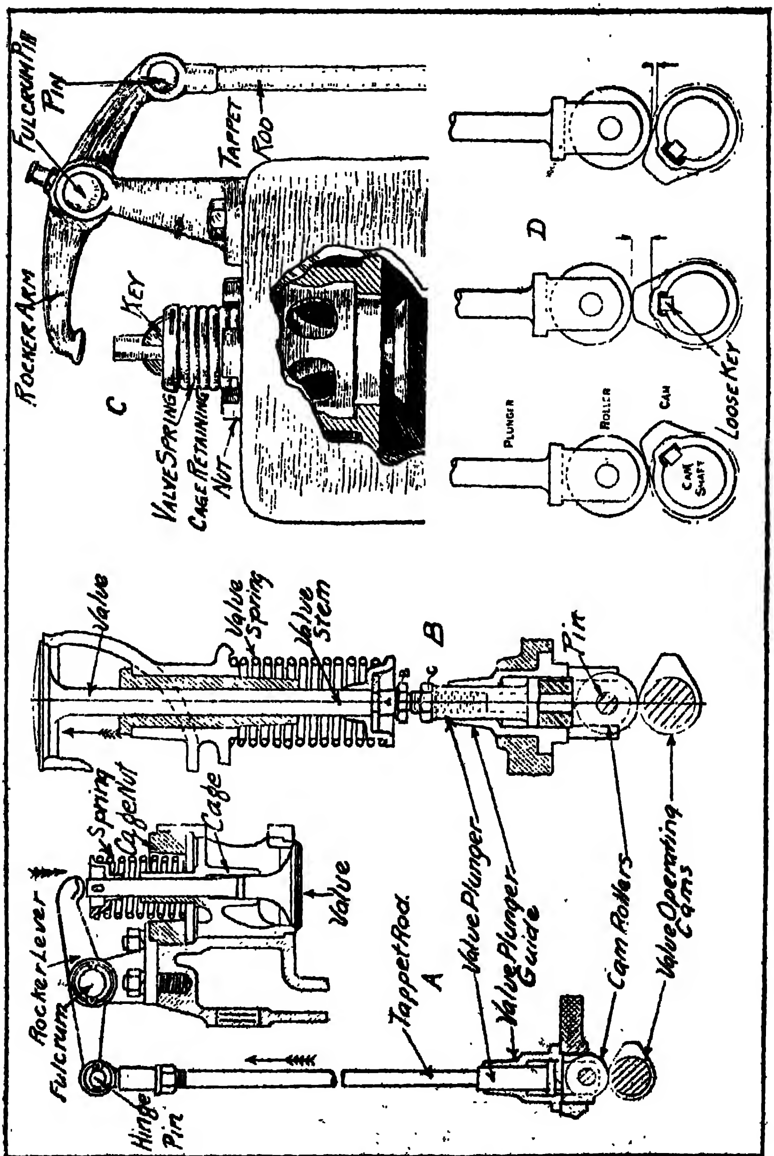


Fig. 123.—Points in the Valve Operating Mechanism That Demand Attention.

to lengthen the valve stem by some means in order to reduce the excessive clearance. The only remedy for wear at the various hinges and bearing pins is to bore the holes out slightly larger and to fit new hardened steel pins of larger diameter. Depreciation between the valve plunger guide and the valve plunger is usually remedied by fitting new plunger guides in place of the worn ones. If there is sufficient stock in the plunger guide casting as is always the case when these members are not separable from the cylinder casting, the guide may be bored out and bushed with a light bronze bushing.

Another point where depreciation must be looked for is between the valve stem and the valve stem guide in the cylinder. The methods of repairing this defect are clearly indicated at Fig. 124. A common cause of irregular engine operation is due to a sticking valve, which condition is clearly depicted at Fig. 123, C. This may be due to a bent valve stem, a weak or broken valve spring or an accumulation of burnt or gummed oil between the valve stem and the valve stem guide. In order to prevent this the valve stem must be smoothed with fine emery cloth and no burrs or shoulders allowed to remain on it, and the stem must also be straight and at right angles to the valve head. If the spring is weak it may be strengthened in some cases by stretching it out so that a larger space will exist between the coils. Obviously if a spring is broken the only remedy is replacement of the defective member.

A number of engines of old patterns had cams keyed to the camshaft instead of formed integrally with it as is now common practice. After the engine had been used for a time, especially if the valve springs were stiff, the key was very apt to become loose in the cam which would result in a pronounced knock when the engine was in operation. The reason for this knock may be clearly understood by referring to illustration at Fig. 123, D. With the key slot worn, as the cam started to lift the plunger the pressure against the cam would cause that member to come back against the key sharply and the hammering action would cause noise. Similarly when the cam left the plunger the looseness would again be evidenced and another knock would result. Where

this form of fastening is used the only remedy for worn keyway in the cam is to use wider keys in the camshaft by providing new keyways in that member. While it is possible to cure the trouble by using a two diameter key, this is not considered good practice owing to difficulties in properly fitting such a member.

Mention has been made of wear in the valve stem guide and its influence on engine action. When these members are an integral part of the cylinder the only method of compensating for this wear is to drill the guide out and fit a bushing, which may be made of steel tube. In order to insure that the hole will be bored out true a simple jig is extemporized from one of the valve chamber caps as indicated. The cap used is the member carrying the spark plug and the opening left for this member is filled with a threaded bushing carrying a plain hardened steel bushing intended for the drill guide. As it is not always possible to procure steel tubing of the proper size it may be necessary to drill out or ream out the bore of the tube to fit the valve stem after the bushing is driven in place.

In most engines, especially those of recent development, the valve stem guide is driven into the cylinder casting and is a separate member which may be removed when worn and replaced with a new one. When the guides become enlarged to such a point that considerable play exists between them and the valve stems, they may be easily knocked out by using a drift pin of the proper size and a hammer or forced out under an arbor press. This is not a difficult thing to do, as one need not be afraid of injuring a member which is no longer of any use. Care must be taken, however, in placing the new valve stem guide because, while this might be hammered in place, it could not be done unless extreme care was exercised and there would always exist the possibility of injuring the guide. The approved method of installing a new valve stem guide is shown at Fig. 124, C. A cold rolled steel rod is threaded practically its entire length and is of sufficient diameter to just fit into the hole in the guide. A substantial piece of flat stock E, is placed over the valve chamber, this being at least one-quarter inch thick and one inch wide and of such length as to bridge the valve cap opening over and leave a liberal margin

at either side. The nut A, is screwed down on the rod B, until the nut C, at the lower end of the rod is bearing tightly against the valve stem guide G. The guide member is then forced into place by turning either or both of the nuts A, or C, until it is firmly seated. It is possible to use a long bolt instead of the rod B, if desired. When this system of valve guide construction is followed, the work of replacing the worn members can be

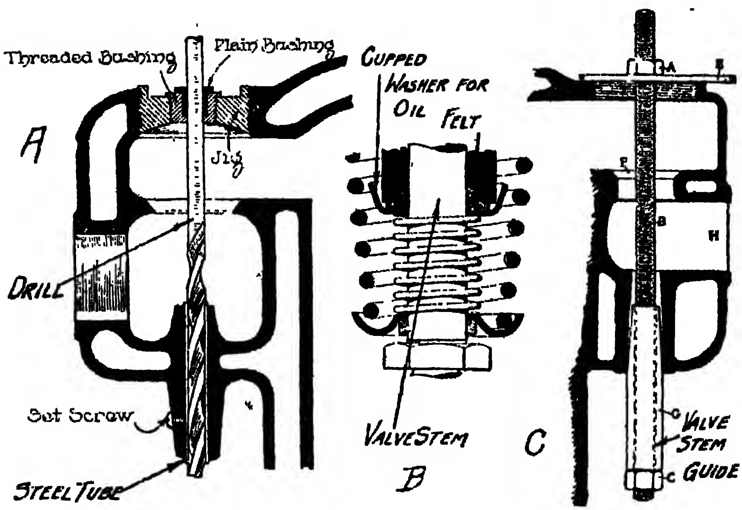


Fig. 124.—Practical Methods of Restoring Worn Valve Stem Guide Bushing.

done by one without mechanical experience just as well as by the more expert.

The depreciation of the exposed valve stem guides may be reduced considerably by adopting the scheme for lubricating the valve stems shown at Fig. 124, E, used on Overland cars. This consists of cutting out the lower portion of the valve stem guide to take a beveled felt washer which is kept firmly pressed against the seating by a cupped steel washer maintained in contact against the felt by a coil spring extending down to the valve spring collar and fitting the valve stem fairly close. The shape of the cupped

washer makes it possible to fill that member with oil which is absorbed by the felt and distributed against the valve stem as it reciprocates up and down. On practically all motors of recent design, provision is made for enclosing the valve stems and plungers in order to keep out dirt and grit and to retain lubricating oil splashed on the working surfaces from the crankcase interior or forced out through the valve operating plunger guides because of internal crankcase pressure.

Piston Troubles.—If an engine has been entirely dismantled it is very easy to examine the pistons for deterioration. The relation of the piston, connecting rod and crankshaft of a typical power plant is clearly outlined at Fig. 125 and below the assembled group both the connecting rod and piston are shown dismantled. While it is important that the piston be a good fit in the cylinder it is mainly upon the piston rings that compression depends. The piston should fit the cylinder with but little looseness, the usual practice being to have the piston about .001-inch smaller than the bore for each inch of piston diameter at the point where the least heat is present or at the bottom of the piston. It is necessary to allow more than this at the top of the piston owing to its expansion due to the direct heat of the explosion. The clearance is usually graduated and a piston that would be .005-inch smaller than the cylinder bore at the bottom would be about .0065-inch at the middle and .0075-inch at the top. If much more play than this is evidenced the piston will "slap" in the cylinder and the piston will be worn at the ends more than in the center. Pistons sometimes warp out of shape and are not truly cylindrical. This results in the high spots rubbing on the cylinder while the low spots will be blackened where a certain amount of gas has leaked by.

Mention has been previously made of the necessity of reboring or regrinding a cylinder that has become scored or scratched and which allows the gas to leak by the piston rings. When the cylinder is ground out, it is necessary to use a larger piston to conform to the enlarged cylinder bore. Most manufacturers are prepared to furnish over-size pistons, there being four standard over-size dimensions adopted by the S. A. E. for rebored cylinders. These are .010-inch, .020-inch, .030-inch, and .040-inch larger than the

regular dimension. Care should be taken in reboring the cylinders to adhere as closely as possible to one or the other of these standards.

If the engine construction is such that side plates may be removed from the crank case and the cylinder head removed from the cylinders it is possible to remove a piston for inspection with-

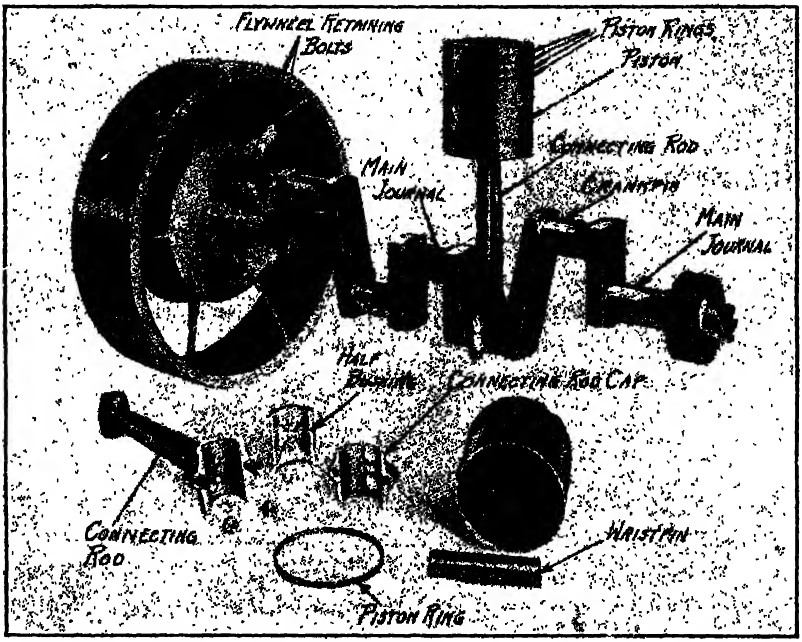


Fig. 125.—Typical Piston, Connecting Rod and Crankshaft Assembly.

out taking down the entire motor. As will be noted at Fig. 126. when the side plate is removed from the engine base a large opening is left through which the connecting rod cap nuts may be easily reached with an ordinary S wrench. After the cap is removed from the connecting rod it is not difficult to push the connecting rod and piston assembly out through the opening left at the top of the cylinder.

All gas engine pistons are provided with two or more packing rings and it is these members that frequently need inspection,

rather than the piston itself. The common forms of piston rings used are outlined at Fig. 127. The different types shown are fitted to one piston, though the usual practice is to use rings of the same type in each group. The ring shown at Fig. 127, A, has a diagonal cut joint and has been widely applied. That depicted at B, has a lapped or step joint, and is superior to the form shown above it, inasmuch as it will retain gas in a more positive manner. The butt joint ring shown at C, is seldom used on automobile en-

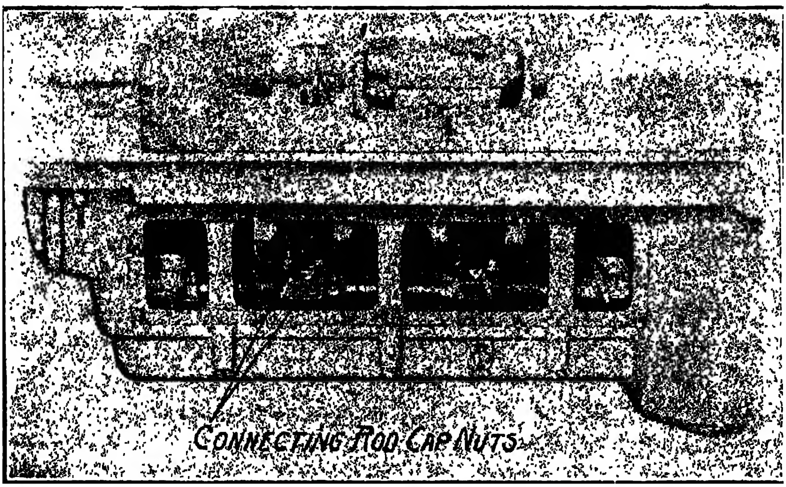


Fig. 126.—Showing how Connecting Rod Caps May be Reached Through Inspection Holes in the Side of the Crankcase.

gines though it is sometimes applied to cheap stationary or marine types. The use of a number of light steel rings instead of one wide ring in the groove is found on a number of the 1915 automobile power plants. It is contended that where a number of light rings is employed a more flexible packing means is obtained and the possibility of leakage is reduced. Rings of this design are made of square section steel wire and are given a spring temper. Owing to the limited width the diagonal cut joint is generally employed instead of the lap joint which is so popular on wider rings. This construction is clearly outlined at Fig. 127, D.

Leak Proof Piston Rings.—In order to reduce the compres-

sion loss and leakage of gas by the ordinary simple form of diagonal or lap joint one-piece piston ring a number of compound rings have been devised and are offered to the repairman to use in making replacements. The leading forms are shown at Fig. 128. That shown at A, is known as the "Statite" and consists of three rings, one carried inside while the other two are carried on the outside. The ring shown at B, is a double ring and is known as the McCadden. This is composed of two thin concentric lap joint rings so disposed relative to each other that the opening in the inner ring comes opposite to the opening in the outer ring. The form shown at C is known as the "Leektite," and is a single ring provided with a peculiar form of lap and dove tail joint. The ring shown at D, is known as the "Dunham" and is of the double concentric type being composed of two rings with lap joints which are welded together at a point opposite the joint so that there is no passage by which the gas can escape. The Burd high compression ring is shown at E. The joints of these rings are sealed by means of an H shaped coupler of bronze which closes the opening. The ring ends are made with tongues which interlock with the coupling. The ring shown at F, is called the "Evertite" and is a three-piece ring composed of three members as shown in the sectional view below the ring. The main part or inner ring

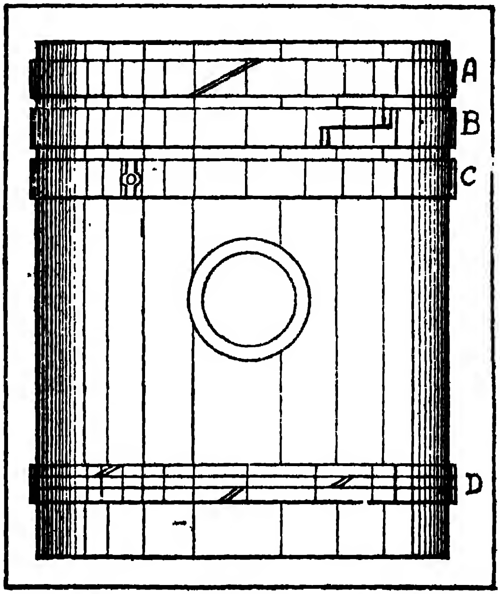


Fig. 127.—Forms of Piston Rings Commonly Used.

has a circumferential channel in which the two outer rings lock, the resulting cross-section being rectangular just the same as that of a regular pattern ring. All three rings are diagonally split and the joints are spaced equally and the distances maintained by small pins. This results in each joint being sealed by the solid portion of the other rings.

The piston rings should be taken out of the piston grooves and all carbon deposits removed from the inside of the ring and the

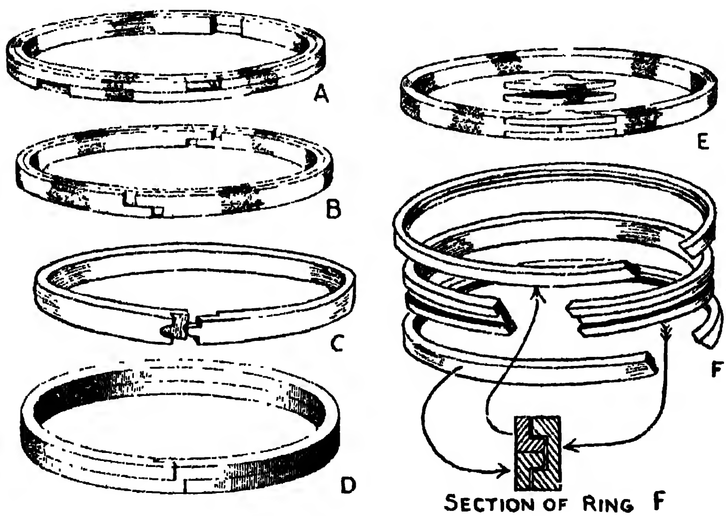


Fig. 128.—Leak Proof and Other Compound Piston Rings.

bottom of the groove. It is important to take this deposit out because it prevents the rings from performing their proper functions by reducing the ring elasticity, and if the deposit is allowed to accumulate it may eventually result in sticking and binding of the ring, this producing excessive friction or loss of compression. When the rings are removed they should be tested to see if they retain their elasticity and it is also well to see that the small pins in some pistons which keep the rings from turning around so the joints will not come in line are still in place. If no pins are found

there is no cause for alarm because these dowels are not always used. When fitted, they are utilized with rings having a butt joint or diagonal cut as the superior gas retaining qualities of the lap or step joint render the pins unnecessary.

If gas has been blowing by the ring or if these members have not been fitting the cylinder properly the points where the gas passed will be evidenced by burnt, brown or roughened portions

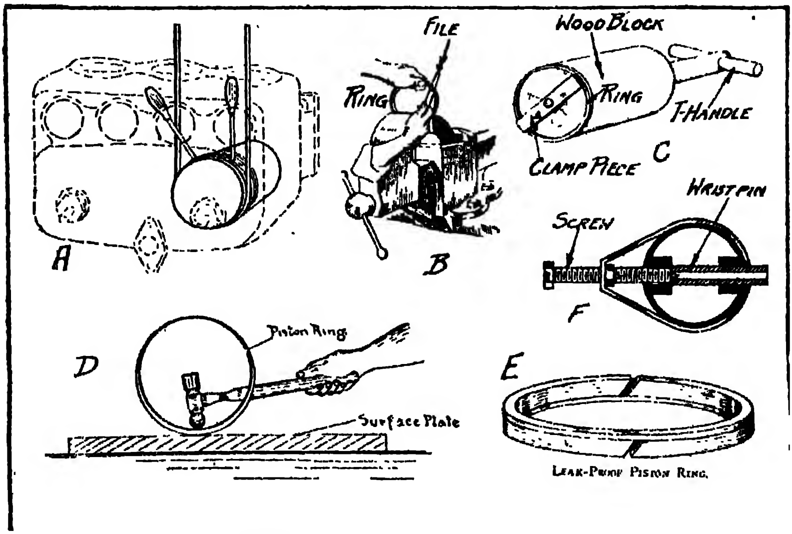


Fig. 129.—Processes Incidental to Piston Ring Restoration.

of the polished surface of the pistons and rings. The point where this discoloration will be noticed more often is at the thin end of an eccentric ring, the discoloration being present for about ½-inch or ¾-inch each side of the slot. It may be possible that the rings were not true when first put in. This made it possible for the gas to leak by in small amounts initially which increased due to continued pressure until quite a large area for gas escape had been created.

Removing Pistons Stuck in Combustion Chamber.—The removal and replacement of pistons and rings seldom offer any

trouble if the work is properly carried on, but if for any reason the piston should be pushed too far up into the cylinder on some types of engines the top ring will expand into the combustion chamber and will lock the pistons tightly in place. This is a difficult condition to overcome with some forms of cylinders though if the cylinder casting is of the L or T form it may be possible to compress the rings sufficiently to remove the piston by simple means.

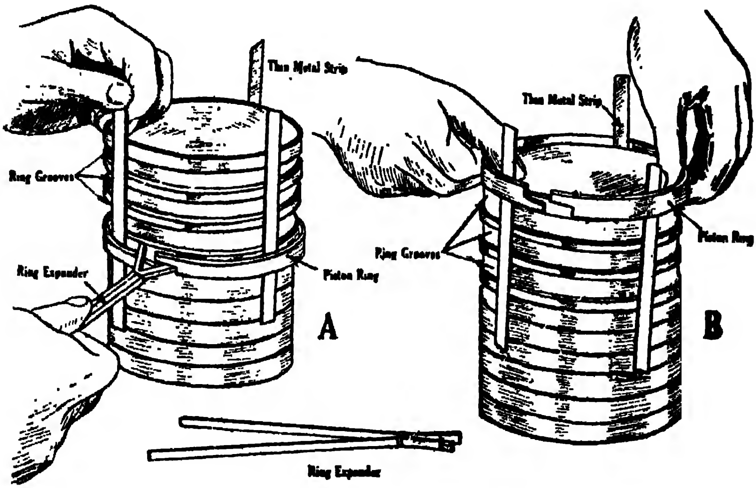


Fig. 130.—Simple Method of Removing or Installing Piston Rings.

The best method is shown at Fig. 129, A. A very thin strip of metal of approximately the same width as the piston rings is passed through one of the valve chamber openings and passed around the piston and pulled out through the other opening. It requires the services of two people and sometimes three to remove a piston stuck in this manner. The efforts of one are directed to keep the band taut under the ring and to exert an upward pull which forces that portion of the ring embraced by the metal band to fill the groove in the piston. Another person uses a pair of screw drivers, one through each valve chamber opening to compress the ring at the

points indicated in the drawing. This means that a three point compressional effect is obtained and it is a simple matter for the third person to draw the piston back into the cylinder when the ring has been properly compressed in its groove. It is not always possible to compress the ring so the only other alternative is to break it in a number of pieces by hitting the brittle ring with a drift or chisel and then withdrawing the pieces one at a time until

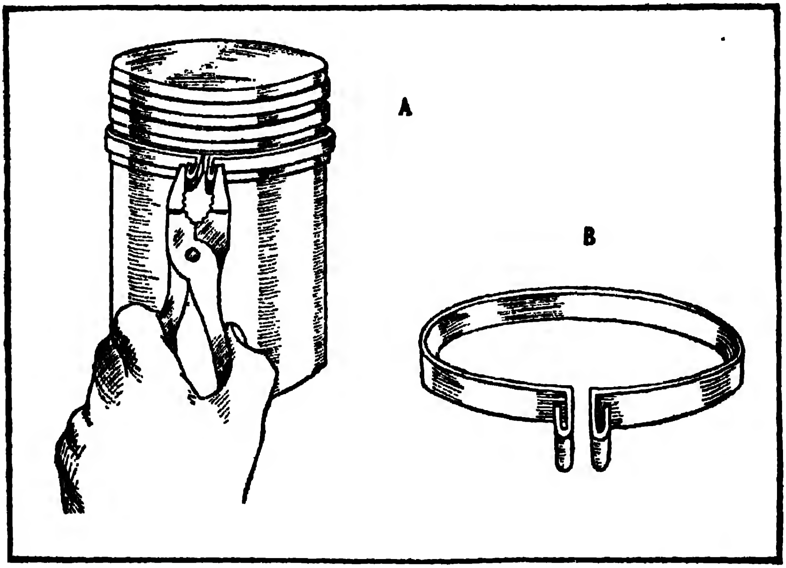


Fig. 131.—Simple Clamp for Closing Piston Ring to Facilitate Insertion in Cylinders.

the ring has been entirely removed. With the T-head cylinder it is sometimes possible to remove the ring without the use of the metal bands, as that member is compressed at diametrically opposite points by a screw driver inserted through each valve chamber cap.

Piston Ring Manipulation.—Removing piston rings is a difficult operation if the proper means are not taken, but is a comparatively simple one when the trick is known. The tools required are very simple, being three strips of thin steel about

one-quarter inch wide and four or five inches long and a pair of spreading tongs made up of one-quarter inch diameter key-stock tied in the center with a copper wire to form a hinge. The construction is such that when the hand is closed and the handles brought together the other end of the expander spreads out, an action just opposite to that of the conventional pliers. The method of using the tongs and the metal strips is clearly indicated at Fig. 130. At A the ring expander is shown spreading the ends of the rings sufficiently to insert the pieces of sheet metal between one of the rings and the piston. Grasp the ring as shown at B, pressing with the thumbs on the top of the piston and the ring will slide off easily, the thin metal strips acting as guide members to prevent the ring from catching in the other piston grooves. Usually no difficulty is experienced in removing the top or bottom rings, as these members may be easily expanded and worked off directly without the use of a metal strip. When removing the intermediate rings, however, the metal strips will be found very useful. These are usually made by the repairman by grinding the teeth from old hacksaw blades and rounding the edges and corners in order to reduce the liability of cutting the fingers. By the use of the three metal strips a ring is removed without breaking or distorting it and practically no time is consumed in the operation.

Fitting Piston Rings.—Before installing new rings, they should be carefully fitted to the grooves to which they are applied. The tools required are a large piece of fine emery cloth, a thin, flat file, a small vise with copper or leaden jaw clips, and a smooth hard surface such as that afforded by the top of a surface plate or a well planed piece of hard wood. After making sure that all deposits of burnt oil and carbon have been removed from the piston grooves, three rings are selected, one for each groove. The ring is turned all around its circumference into the groove it is to fit, which can be done without springing it over the piston as the outside edge of the ring may be used to test the width of the groove just as well as the inside edge. The ring should be a fair fit and while free to move circumferentially there should be no appreciable up and down motion. If the ring is a tight fit it should be laid edge down upon

the piece of emery cloth which is placed on the surface plate and carefully rubbed down until it fits the groove it is to occupy. It is advisable to fit each piston ring individually and to mark them in some way to insure that they will be placed in the groove to which they are fitted.

The repairman next turns his attention to fitting the ring in the cylinder itself. The ring should be pushed into the cylinder at least two inches up from the bottom and endeavor should be made to have the lower edge of the ring parallel with the bottom of the cylinder. If the ring is not of correct diameter, but is slightly larger than the cylinder bore, this condition will be evident by the angular slots of the rings being out of line or by difficulty in inserting the ring if it is a lap joint form. If such is the case the ring is removed from the cylinder and placed in the vise between the soft metal jaw clips, as shown at Fig. 129, B. Sufficient metal is removed with a fine file from the edges of the ring at the slot until the edges come into line and a slight space exists between them when the ring is placed into the cylinder. It is important that this space be left between the ends, for if this is not done when the ring becomes heated the expansion of metal may cause the ends to abut and the ring to jam in the cylinder.

Another method of fitting a piston ring is indicated at Fig. 129, C. A plug is made of soft wood, such as yellow pine that will be an easy fit in the cylinder and one end is turned down enough so that a shoulder will be formed to back the ring. The turned down portion should be a little less than the width of the ring to be tested. The ring is pushed on this turned down end of the wooden plug and held by a small batten secured by a screw in the center. This does not hold the ring tightly enough to keep it from closing up. It is also important to turn the end of the wooden plug small enough so that its diameter will be less than the bore of the ring when that member is tightly closed. The cylinder bore is smeared with a little Prussian blue pigment which is spread evenly over the cylinder wall with a piece of waste and the ring is moved back and forth in the cylinder while it is held square by the shoulder on the plug. The high spots on the ring will be shown by color. Usually the ring will be found to bear hardest

at each side of the slot. These high spots are removed carefully with a very fine mill file or piece of emery cloth and the ring is again inserted in the cylinder bore to find other high spots which are removed in a similar manner. When the rings fit fairly well all around, the entire surface will have a uniform coating of blue.

If the old piston rings are bright all around but appear to have lost their elasticity, a new lease of life may be given by a process known as peening which is shown at Fig. 129, D. The ring is stood on a surface plate and is tapped inside with the peen end of a light hammer, using the harder blows at the thick section and gradually reducing the force of the blow as the slot is approached. If skillfully done a ring may be stretched to some extent and considerable elasticity imparted. Piston rings are not always of the simple form shown at Fig. 127. Various duplex constructions have been offered with an idea of reducing the possibility of leakage. A ring of this type which is known as the "Leak Proof" piston packing is shown at Fig. 129, E. These duplex rings are harder to install than the simpler forms, and it is important that they be carefully fitted to the cylinder and to the piston grooves.

It is necessary to use more than ordinary caution in replacing the rings on the piston because they are usually made of cast iron, a metal that is very fragile and liable to break because of its brittleness. Special care should be taken in replacing new rings as these members are more apt to break than old ones. This is probably accounted for by the heating action on used rings which tends to anneal the metal as well as making it less springy. The bottom ring should be placed in position first which is easily accomplished by springing the ring open enough to pass on the piston and then sliding it into place in the lower groove which on some types of engines is below the wrist pin, whereas in others all grooves are above that member. The other members are put in by a reversal of the process outlined at Fig. 130. It is not always necessary to use the guiding strips of metal when replacing rings as it is often possible, by putting the rings on the piston a little askew and manœuvering them to pass the grooves without springing the

ring into them. The top ring should be the last one placed in position.

Before replacing pistons in the cylinder one should make sure that the slots in the piston rings are spaced equidistant on the piston and if pins are used to keep the ring from turning one should be careful to make sure that these pins fit into their holes in the ring and that they are not under the ring at any point. Practically all cylinders are chamfered at the lower end to make insertion of piston rings easier. The operation of putting on a cylinder casting over a piston really requires two pairs of hands, one to manipulate the cylinder, the other person to close the rings as they enter the cylinder. This may be done very easily by a simple clamp member made of sheet brass or iron and used to close the ring as indicated at Fig. 131, A. It is apparent that the clamp which is shown at D, must be adjusted to each individual ring and that the split portion of the clamp must coincide with the split portion of the ring. The cylinder should be well oiled before attempt is made to install the pistons. The engine should be run with more than the ordinary amount of lubricant for several days after new piston rings have been inserted. On first starting the engine, one may be disappointed in that the compression is even less than that obtained with the old rings. This condition will soon be remedied as the rings become polished and adapt themselves to the contour of the cylinder. It will take fully 100 miles of road work to bring the rings to a sufficiently good fit so that a marked improvement in the compression will be noticed.

How Wrist Pins Are Held.—While the repairman is working on the pistons there is one important member of the piston assembly that should receive attention and that is the pin on which the upper end of the connecting rod swings. These are held in place in a variety of ways, the most common of which are shown at Fig. 132. In some forms of pistons the piston pin is a tight fit in the bosses and it is necessary to force it out. The method of doing this is clearly outlined at Fig. 129, F. This calls for the use of a special clamp fitting having a hole at one side sufficiently large for the wrist pin to pass through and carrying a forcing screw at the other. The screw passes through a nut which is kept

from turning by bending the band around it. Any motion of the screw that will advance it into the nut will tend to force out the wrist pin without injuring that member.

The means of locking the wrist pin in place that have been used are legion, but those depicted are the most common. That

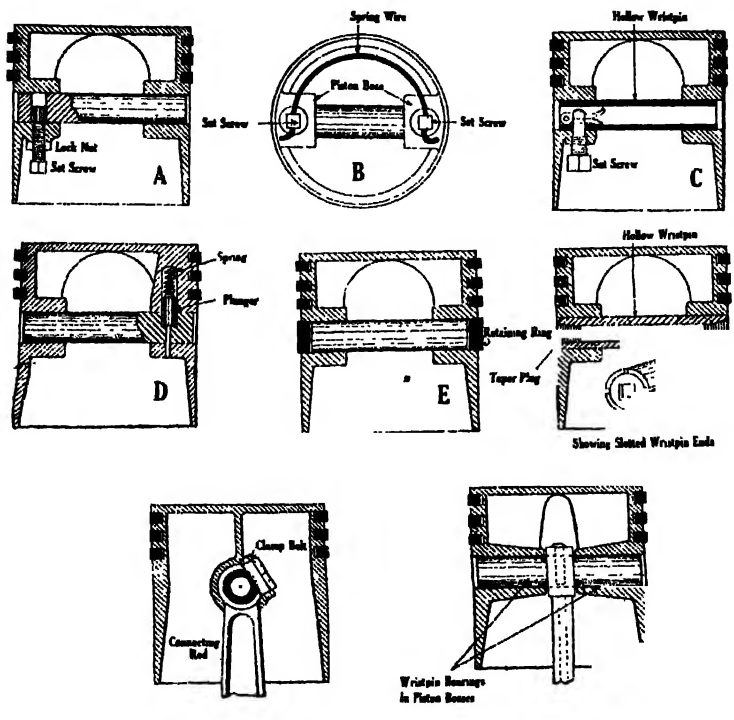


Fig. 132.—Conventional Methods of Piston Pin Retention.

at A, involves the use of a set screw passing through one of the piston bosses and into the wrist pin as indicated. This method is not the preferred construction on account of the liability of the lock nut to become loose and the set screw to unscrew itself from vibration and drop into the engine base where it may do con-

siderable damage. When locking screws are employed, the methods of retention shown at B and C, are considered superior. In the former holes are drilled through the heads of the set screws and a piece of spring wire passed through them as indicated. Where a hollow wrist pin is used the end of the set screw may be provided with a hole to receive a split pin. The method of keeping the wrist pin in place shown at D, involves the use of a spring pressed plunger which is housed in a suitable boss cast on one side of the piston. In order to remove a wrist pin held by this method it is necessary to use a piece of stiff wire such as a bicycle spoke and to push the plunger back out of the wrist pin. The wrist pin is then moved slightly to one side so that the end of the plunger will rest on the wrist pin and the piece of stiff wire removed. It is then an easy matter to push the wrist pin out of the bosses. The method depicted at E, is self-explanatory, a retaining ring similar in construction to a piston ring, but somewhat wider passing entirely around the piston in a suitable groove cut around the zone of the wrist pin bosses. The method outlined at F, received wide application on earlier engines, but is not much used at the present time. In this the hollow wrist pin was slotted at four points at each end, and was provided with a tapering thread into which a correspondingly formed plug was screwed to expand the wrist pin against the bosses. In all of the forms outlined, the wrist pin is to be held from rotation while the connecting rod oscillates on it. In the form shown at G, the wrist pin oscillates in the piston bosses and the connecting rod is tightly clamped to the wrist pin by a suitable clamp bolt. To remove the wrist pin it is necessary to take out the clamp bolts which will permit the piston boss to spread enough to release its hold on the wrist pin.

Wrist Pin Wear.—While wrist pins are usually made of very tough steel, case hardened with the object of wearing out an easily renewable bronze bushing in the upper end of the connecting rod rather than the wrist pin it sometimes happens that these members will be worn so that even the replacement of a new bushing in the connecting rod will not reduce the lost motion and attendant noise due to a loose wrist pin. The only remedy is to fit new wrist pins to the piston. Where the connecting rod is clamped to the

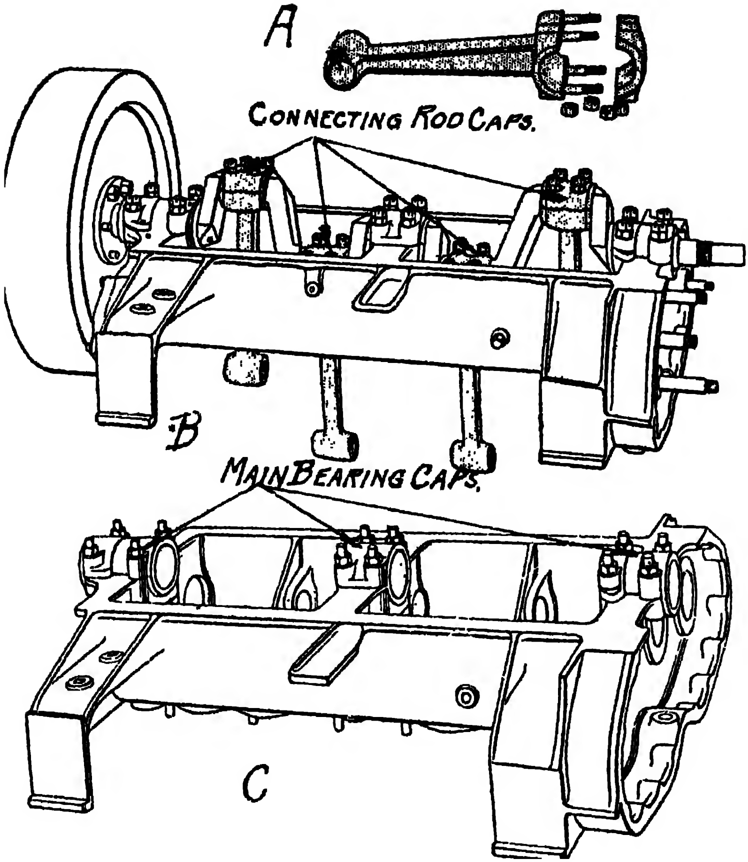


Fig. 133.—Showing Method of Supporting Crankcase to Provide Ready Access to Connecting Rods and Crankshaft Bearings.

wrist pin and that member oscillates in the piston bosses the wear will usually be indicated on bronze bushings which are pressed into the piston bosses. These are easily renewed and after running a reamer through them of the proper size no difficulty should be experienced in replacing either the old or a new wrist pin depending upon the condition of that member.

Inspection and Refitting of Engine Bearings.—While the engine is dismantled one has an excellent opportunity to examine the various bearing points in the engine crankcase to ascertain if any looseness exists due to depreciation of the bearing surfaces. As will be evident from the views at Figs. 133 and 134, both main crankshaft bearings and the lower end of the connecting rods may be easily examined for deterioration. With the rods in place as shown at Fig. 133, A, it is not difficult to feel the amount of lost motion by grasping the connecting rod firmly with the hand and

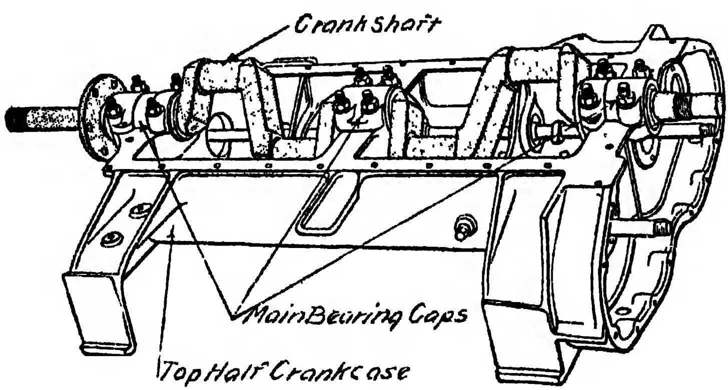


Fig. 134.—Top Half of Crankcase Showing Method of Crankshaft Retention by Three Main Bearing Caps.

moving it up and down. The appearance of the engine base after the connecting rods and flywheel have been removed from the crankshaft is shown at Fig. 134, while the appearance of the upper portion of the crankcase after the crankshaft is removed is clearly shown at Fig. 133, C.

After the connecting rods have been removed and the flywheel taken off the crankshaft to permit of ready handling, any looseness in the main bearing may be detected by lifting up on either the front or rear end of the crankshaft and observing if there is any lost motion between the shaft journal and the main bearing caps.

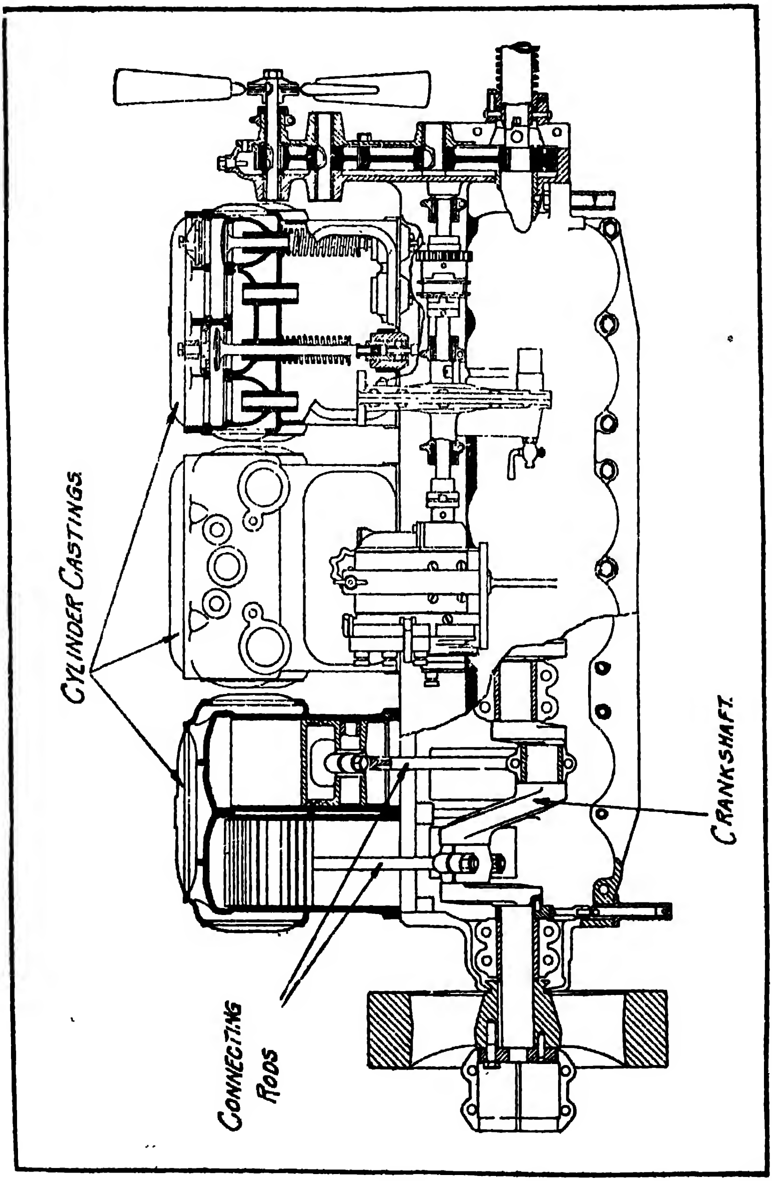


Fig. 135.—Part Sectional View of the Winton Six Cylinder Engine, an Unconventional Design, Having the Crank Case Divided on Vertical Instead of Horizontal Center Lines.

It is not necessary to take an engine entirely apart to examine the main bearings as in some forms these may be readily reached by removing a large inspection plate either from the bottom or side of the engine crank case. In the Winton engine, which is shown at Fig. 135, a distinctive method of crank case construction is used in which that member is divided vertically instead of horizontally as is the usual practice. One-half of the crank case may be removed, this leaving the crankshaft and connecting rods supported by the other half. It is not necessary to remove the cylinder casting to gain access to the crank case interior. This type of construction is rare, however, and is found only on the engine design outlined. The symptoms of worn main bearings are not hard to identify. If an engine knocks when a vehicle is traveling over level roads regardless of speed or spark lever position and the trouble is not due to carbon deposits in the combustion chamber one may reasonably surmise that the main bearings have become loose or that lost motion may exist at the connecting rod big ends, and possibly at the wrist pins. The main journals of any well designed engine are usually proportioned with ample surface and will not wear unduly unless lubrication has been neglected. The connecting rod bearings wear quicker than the main bearings owing to being subjected to a greater unit stress and it may be necessary to take these up several times in a season if the car is driven to any extent. Main bearings should run for ten thousand miles without attention in a properly built engine that has always been well oiled. Most connecting rod bearings will loosen up enough to be taken up in five thousand miles.

Adjusting Main Bearings.—When the bearings are not worn enough to require refitting the lost motion can often be eliminated by removing one or more of the thin shims or liners ordinarily used to separate the bearing caps from the seat. These are shown at Fig. 131, A. Care must be taken that an even number of shims of the same thickness are removed from each side of the journal. If there is considerable lost motion after one or two shims have been removed, it will be advisable to take out more shims and to scrape the bearing to a fit before the bearing cap is tightened up. It may be necessary to clean up the crankshaft journals as these

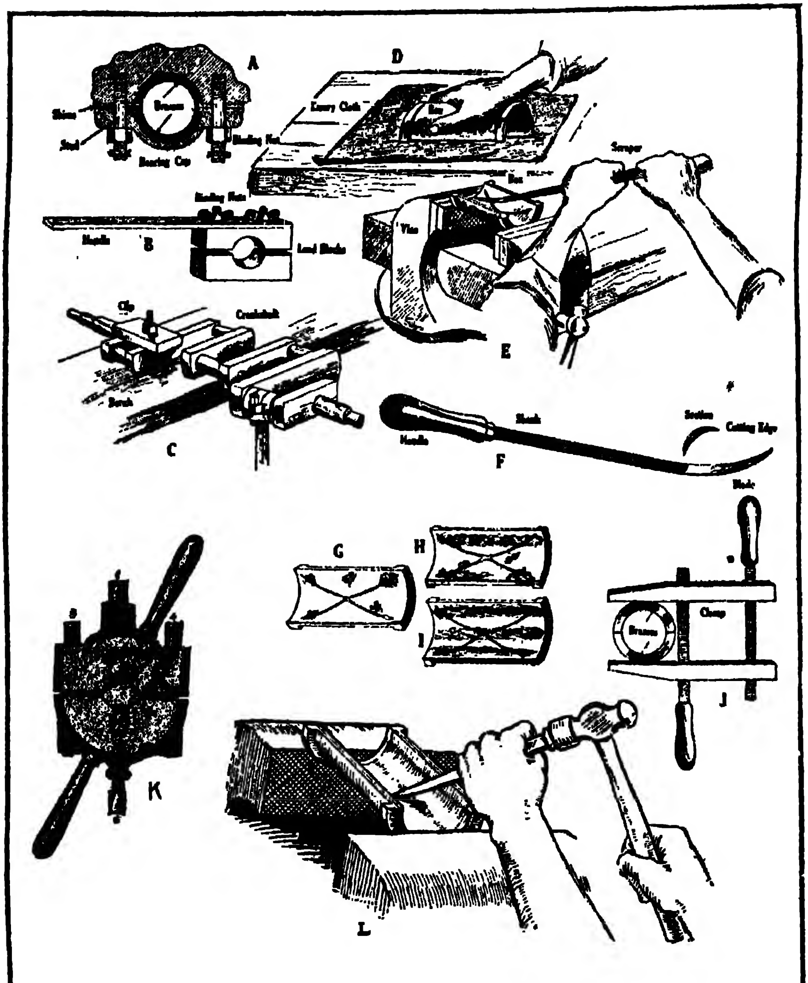


Fig. 136.—Processes and Tools Necessary for Bearing Restoration.

may be scored due to not having received clean oil or having had bearings seize upon them. It is not difficult to true up the crank pins or main journals if the score marks are not deep. A fine file and emery cloth may be used, or a lapping tool such as depicted at Fig. 136, B. The latter is preferable because the file and emery

cloth will only tend to smooth the surface while the lap will have the effect of restoring the crank to proper contour.

A lapping tool may be easily made as shown at B, the blocks being of lead or hard wood. As the width of these are about half that of the crank pin the tool may be worked from side to side as it is rotated. Another form of lapping tool and the method of using it which is practically the same as that we are now describing is shown at Fig. 139. An abrasive paste composed of fine emery powder and oil is placed between the blocks, and the blocks are firmly clamped to the crank pin. While the approved method is to place the shaft between lathe centers as shown at Fig. 141, and revolve it slowly, guiding the lapping tool with the hand as the shaft revolves, the lathe is not always available. In that case the crankshaft may be clamped to the work bench as indicated at Fig. 136, C, and the lapping tool turned by hand around the stationary crankshaft. It may not be necessary to remove the crankshaft from the engine base as a lapping tool may be used without difficulty under the conditions shown at Fig. 139, C. As the lead blocks bend down, the wing nut should be tightened to insure that the abrasive will be held with some degree of pressure against the shaft. A liberal supply of new abrading material is placed between the lapping blocks and crankshaft from time to time and the old mixture cleaned off with gasoline. It is necessary to maintain a side to side movement of the lapping tool in order to have the process affect the whole width of the crank pin equally. The lapping is continued until a smooth surface is obtained.

If a crank pin is worn out of true to any extent the only method of restoring it is to have it ground down to proper circular form by a competent mechanic having the necessary machine tools to carry on the work accurately. In order to support a crankshaft in a lathe or grinding machine special forms of dogs may be used or special crankshaft supporting flanges may be made of cast iron. An adjustable dog is shown at Fig. 140, A. This has a movable center pad which can be moved up and down to provide for varying distances between the center line of the crank pin and the crankshaft when turning the crankpins. It is not difficult to support a crankshaft in a lathe when the work is to be done on the

main journal. This can be easily accomplished by the use of regular pattern lathe dogs and back rest as shown at Fig. 141, A. Machining the crank throws is more difficult as the crankshaft must be revolved eccentrically or on the crank pin centers instead of the main journal centers. The use of the special supporting flanges shown at Fig. 140, B, is clearly outlined in the lower portion of Fig. 141. It is necessary to use counterweights in order to balance the weight overhanging the center and to insure smooth rotation of the crank shaft. The journals may be machined either by putting on a very fine feed and using the conventional pattern of turning tools if the shaft is soft, or the journals may be ground if they are hard, if a grinding attachment is available.

The manner in which the adjustable dog or special crankshaft supporting flange works can be easily understood by referring to the drawing at Fig. 140. The distance between the center of the crank pin and crankshaft main journals depends entirely upon the stroke of the piston. This distance is invariably half of the stroke. For example, in an engine having a 5-inch stroke, the distance between the center lines would be 2½ inches. If suitable center holes are drilled in the face of the supporting flange at the proper distances from the crankshaft center it will be possible to line up the flange fittings very accurately to the crank pins and to support the shaft in such a way that the crank pins will revolve on the main center line passing through the lathe centers. This, of course, is essential in order to machine the shaft journal and crank pins true.

After the crankshaft is trued the next operation is to fit it to the main bearings or rather to scrape these members to fit the shaft journal. In order to bring the brasses closer together, it may be necessary to remove a little metal from the edges of the caps to compensate for the lost motion. A very simple way of doing this is shown at Fig. 136, D. A piece of medium emery cloth is rested on the surface plate and the box or brass is pushed back and forth over that member by hand, the amount of pressure and rapidity of movement being determined by the amount of metal it is necessary to remove. This is better than filing because the edges will be flat and there will be no tendency for the bearing

caps to rock when placed against the bearing seat. It is important to take enough off the edges of the boxes to insure that they will grip the crank tightly. The outer diameter must be checked with a pair of calipers during this operation to make sure that the surfaces remain parallel. Otherwise, the bearing brasses will only grip at one end and with such insufficient support they will quickly work loose, both in the bearing seat and bearing cap.

Scraping Brasses to Fit.—To insure that the bearing brasses will be a good fit on the trued up crank pins or crankshaft journals

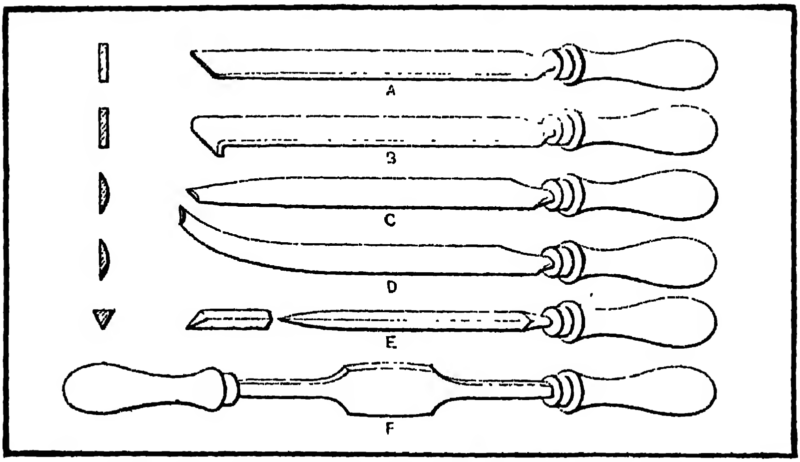


Fig. 137.—Conventional Forms of Bearing Scrapers.

they must be scraped to fit the various crankshaft journals. The process of scraping, while a tedious one, is not difficult, requiring only patience and some degree of care to do a good job. The surface of the crank pin is smeared with Prussian blue pigment which is spread evenly over the entire surface. The bearings are then clamped together in the usual manner with the proper bolts and the crankshaft revolved several times to indicate the high spots on the bearing cap. At the start of the process of scraping in, the bearing may seat only at a few points as shown at Fig. 136, G. Continued scraping will bring the bearing surface as indicated at H, which is a considerable improvement, while the process may be

considered complete when the brass indicates a bearing all over as at I. The high spots are indicated by blue, as where the shaft does not bear on the bearing there is no color. The high spots are removed by means of a scraping tool of the form shown at Fig. 136, F, which is easily made from a worn out file. These are forged to shape and ground hollow as indicated in the section and are kept properly sharpened by frequent rubbing on an ordinary oil stone. To scrape properly, the edge of the scraper must be very keen.

Other forms of scrapers used in machining operations are shown at Fig. 137. The flat scraper A, is used for plain surfaces For ordinary use the blade is about $\frac{3}{16}$-inch thick, about 1-inch wide and is drawn at the point to a thickness of about $\frac{1}{16}$-inch. The cutting edge is made as hard as possible. The hook scraper B, is also used on flat surfaces. The straight and curved half round scrapers shown at C and D, are used for bearings. The three cornered scraper outlined at E, is also used on curved surfaces and is of value in rounding off the sharp corners. For scraping very large engine bearings, such as used for stationary work the two handle scraper shown at F, is valuable, though there are not many applications in automobile work where this type of tool is necessary. The straight or curved half round type works well on soft-bearing metals, such as babbit, or white brass, but on yellow brass or bronze it cuts very slowly, and as soon as the edge becomes dull considerable pressure is needed to remove any metal, this calling for frequent sharpening.

When correcting errors on flat or curved surfaces by hand scraping, it is desirable, of course, to obtain an evenly spotted bearing with as little scraping as possible. When the part to be scraped is first applied to the surface-plate, or to a journal in the case of a bearing, three or four "high" spots may be indicated by the marking material. The time required to reduce these high spots and obtain a bearing that is distributed over the entire surface depends largely upon the way the scraping is started. If the first bearing marks indicate a decided rise in the surface, much time can be saved by scraping larger areas than are covered by the bearing marks; this is especially true of large shaft and engine

bearings, etc. An experienced workman will not only remove the heavy marks, but also reduce a larger area; then, when the bearing is tested again, the marks will generally be distributed somewhat. If the heavy marks which usually appear at first are simply removed by light scraping, these "point bearings" are gradually enlarged, but a much longer time will be required to distribute them.

The number of times the bearing must be applied to the journal for testing is important, especially when the box or bearing is large and not easily handled. The time required to distribute the bearing marks evenly depends largely upon one's judgment in "reading" these marks. In the early stages of the scraping operation, the marks should be used partly as a guide for showing the high areas, and instead of merely scraping the marked spot the surface surrounding it should also be reduced, unless it is evident that the unevenness is local. The idea should be to obtain first a few large but generally distributed marks; then an evenly and finely spotted surface can be produced quite easily.

In fitting brasses when these are of the removable type, two methods may be used. The upper half of the engine base may be inverted on a suitable bench or stand and the boxes fitted by placing the crankshaft in position, clamping down one bearing cap at a time and fitting each bearing in succession until they bed equally. From that time on the bearings should be fitted at the same time so the shaft will be parallel with the bottom of the cylinders. Considerable time and handling of the heavy crankshaft may be saved if a preliminary fitting of the bearing brasses is made by clamping them together with a carpenter's wood clamp as shown at Fig. 136, J, and leaving the crankshaft attached to the bench as shown at C. The brasses are revolved around the crankshaft journal and are scraped to fit wherever high spots are indicated until they begin to seat fairly. When the brasses assume a finished appearance the final scraping should be carried on with all bearings in place and revolving the crankshaft to determine the area of the seating. When the brasses are properly fitted they will not only show a full bearing surface but the shaft will not turn unduly hard if revolved with the same amount of leverage as afforded by

the flywheel rim or starting crank, all bearing caps being properly bedded down and lubricated.

Bearings of white metal or babbitt can be fitted tighter than those of bronze, and care must be observed in supplying lubricant as considerably more than the usual amount is needed until the bearings are run in by several hundred miles of road work. Before the scraping process is started it is well to chisel an oil groove in the bearing as shown at Fig. 136, L. Grooves are very helpful in insuring uniform distribution of oil over the entire width of bearing and at the same time act as reservoirs to retain a supply of oil. The tool used is a round nosed chisel, the effort being made to cut the grooves of uniform depth and having smooth sides. Care should be taken not to cut the grooves too deeply as this will seriously reduce the strength of the bearing bushing. The shape of the groove ordinarily provided is clearly shown at Fig. 136, G, and it will be observed that the grooves do not extend clear to the edge of the bearing, but stop about a quarter of an inch from that point. The hole through which the oil is supplied to the bearing is usually drilled in such a way that it will communicate with the groove.

The tool shown at Fig. 136, K, is of recent development and is known as a "crankshaft equalizer." This is a hand operated turning tool carrying cutters which are intended to smooth down scored crank pins without using a lathe. The feed may be adjusted by suitable screws and the device may be fitted to crank pins and shaft journals of different diameters by other adjusting screws. This device is not hard to operate, being merely clamped around the crankshaft in the same manner as the lapping tool previously described, and after it has been properly adjusted it is turned around by the levers provided for the purpose, the continuous rotary motion removing the metal just as a lathe tool would.

Remetalling and Fitting Connecting Rods.—Fitting and adjusting rod bearings, especially those at the crank pin end, is one of the operations that must be performed several times a season if a car is used to any extent. There are two forms of connecting rods in general use, known respectively as the marine type, shown

at Fig. 138, A, and the hinged form depicted at Fig. 138, B. The hinge type is the simplest, but one clamp bolt being used to keep the parts together as the cap is hinged to the rod end on one side,

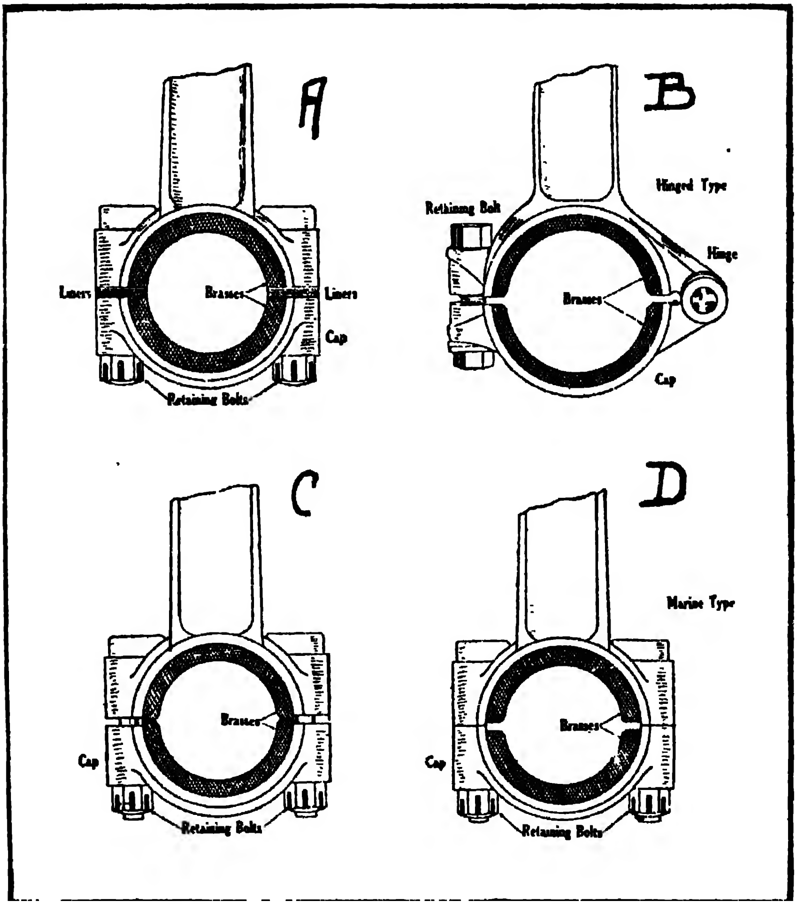


Fig. 138.—Outlining Common Types of Connecting Rod Big Ends.

this permitting the lower portion to swing down and the crank pin to pass out from between the halves when the retaining bolt is removed. In the marine type, which is the most common, one or two bolts are employed at each side and the cap must be removed

entirely before the bearing can be taken off of the crank pin. The tightness of the brasses around the crank pin can never be determined solely by the adjustment of the bolts, as while it is important that these should be drawn up as tightly as possible

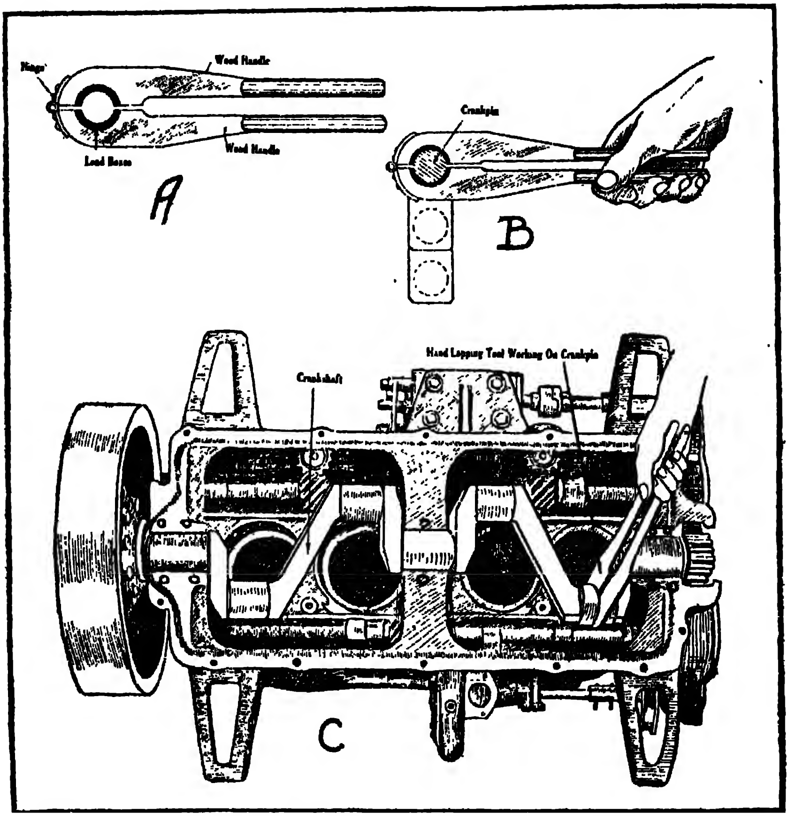


Fig. 139.—Simple Lapping Tool for Crank Pin and Method of Use.

the bearing should fit the shaft without undue binding, even if the brasses must be scraped to insure a proper fit. As is true of the main bearings, the marine form of connecting rod has a number of liners or shims interposed between the top and lower portions of the rod end and these may be reduced in number when necessary to bring the brasses closer together.

In fitting new brasses there are two conditions to be avoided, these being outlined at Fig. 138, C and D. In the case shown at C the light edges of the bushings are in contact, but the connecting rod and its cap do not meet. When the retaining nuts are tightened the entire strain is taken on the comparatively small area of the edges of the bushings which are not strong enough to withstand the strains existing and which flatten out quickly, per-

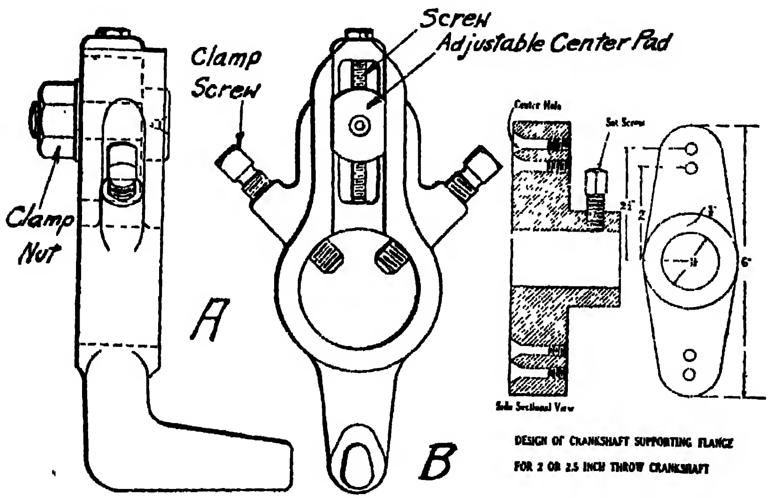


Fig. 140.—Adjustable Center Lathe Dog and Crankshaft Supporting Flange for Use in Turning Crank Pins on Lathes.

mitting the bearing to run loose. In the example outlined at D the edges of the brasses do not touch when the connecting rod cap is drawn in place. This is not good practice, because the brasses soon become loose in their retaining member. In the case outlined it is necessary to file off the faces of the rod and cap until these meet, and to insure contact of the edges of the brasses as well. In event of the brasses coming together before the cap and rod make contact, as shown at C, the bearing halves should be reduced at the edges until both the caps and brasses meet against the surfaces of the liners as shown at A.

Before assembling on the shaft, it is necessary to fit the bearings by scraping, the same instructions given for restoring the contour of the main bearings applying just as well in this case. It is apparent that if the crank pins are not round no amount of scraping will insure a true bearing. A point to observe is to make sure that the heads of the bolts are imbedded solidly in their proper position and that they are not raised by any burrs or

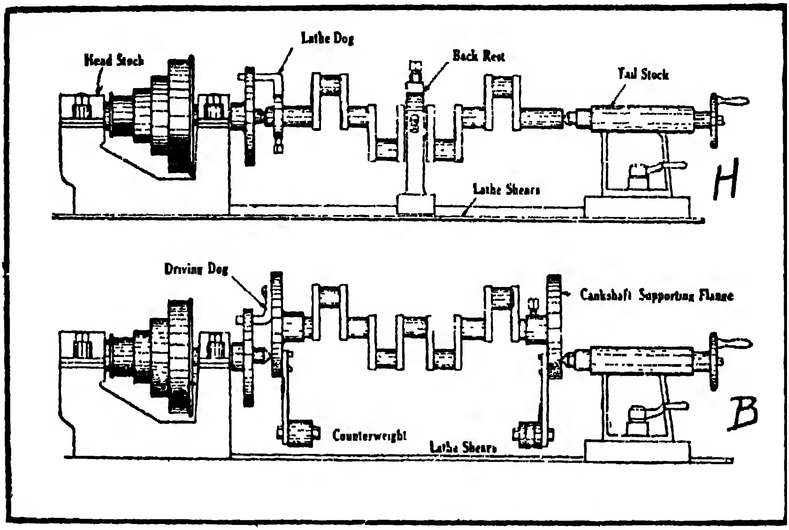


Fig. 141.—At A, Method of Supporting and Driving Crankshaft for Turning Main Bearings. At B, Showing Use of Crankshaft Supporting Flanges when Machining Crank Pins.

particles of dirt under the head which will flatten out after the engine has been run for a time and allow the bolts to slack off. Similarly, care should be taken that there is no foreign matter under the brasses and the box in which they seat. To guard against this the bolts should be struck with a hammer several times after they are tightened up, and the connecting rod can be hit sharply several times under the cap with a wooden mallet or lead hammer. It is important to pin the brasses in place to prevent movement, as lubrication may be interfered with if the bushing turns round

and breaks the correct register between the oil hole in the cap and brasses.

Care should be taken in screwing on the retaining nuts to insure that they will remain in place and not slack off. Spring washers should not be used on either connecting rod ends or main bearing bolts, because these sometimes snap in two pieces and leave the nut slack. The best method of locking is to use well-fitting split pins and castellated nuts. In a number of the cheaper cars, the bearing metal is cast in place in the connecting rod lower end and in main bearings, and is not in the form of removable die cast bushings as are used on the more expensive cars. The repairman who is called upon to replace the bearing metal will find the following instructions regarding remetalling bearings of value. The method described was used by the writer while in charge of a large shop where much work of this kind was done and while the instructions given apply specifically to lining the big ends of connecting rods, the same process may be used successfully on any other bearings where the mandrel and collars can be used, the dimensions being changed to suit the requirements of the worker.

In the case mentioned the journals of the crankshaft were two inches in diameter and the big ends of the connecting rods were worn too much to allow of adjusting. A piece of pipe about 9 inches long was procured and turned down in a lathe until it was a shade under 2 inches in diameter, which made a hollow mandrel of it. A piece of steel tubing could have been used to as good advantage had any been available. As the outside of the bearing caps were machined true a couple of set collars were bored out to be a good fit on the mandrel, and while still in the lathe they were recessed out to just fit over the outside of the big ends, as shown in sketch Fig. 4. One of these collars was placed on the hollow mandrel A, after which the mandrel was pushed through the big end, and the other collar was put on the other side, insuring that the mandrel was as near center as possible for it to be.

The assemblage is then supported on a couple of V-blocks, which are supported on a lathe bed, the ends of the mandrel lying within the V's while the connecting rod hangs between the ways. A piece

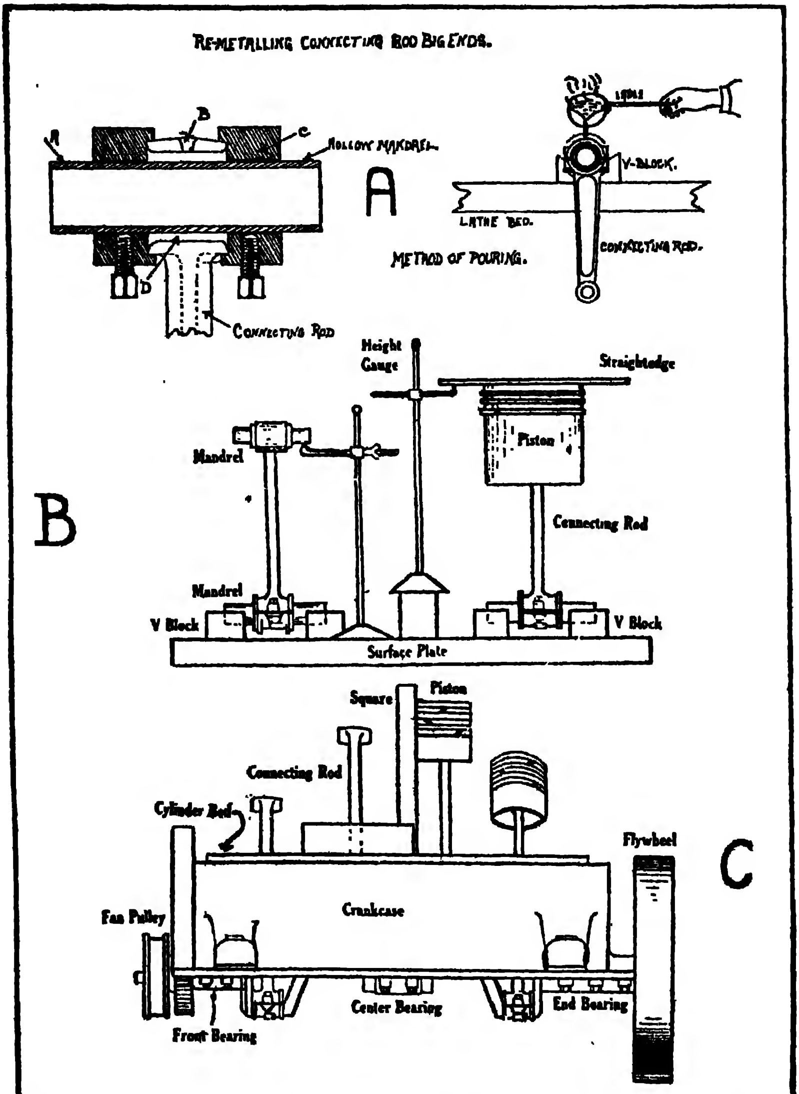


Fig. 142.—Showing Simple Method of Remetalling Connecting Rod Bearings at A, and Ways of Measuring Parallelism of Upper and Lower Connecting Rod Bearings at B and C.

of solid round iron or steel which will go inside of the hollow mandrel should be made red hot while the anti-friction metal is being melted and is pushed inside the mandrel to heat it. In a minute or two the metal may be poured in through B to fill D, and as the metal and the big end caps are well heated the molten metal will flow to every point. The heating of the mandrel can be just as well accomplished by directing the flame from a blow torch or Bunsen burner into the opening. After the metal is poured and has set the whole may be easily cooled by running water through the mandrel or by directing a blast of air against the big end, as desired.

Before the cap is assembled with the connecting rod several shims or liners of sheet brass or copper should be placed between them so that adjustment for wear of the new bearing can be compensated for by the removal of a liner. As is evident, the thinner the liner and the greater the number used, the more sensitive the character of adjustment possible.

The use of a hollow mandrel is to be preferred to a solid one because of the ease with which it can be heated and cooled. Vents should be made for the heated gases by grooving the face of each of the collars nearest the big end and on the same side as the hole through which the metal is poured. If provision is not made for "venting" the molten metal will not run uniformly and will become honeycombed. After cooling the bearing is either bored out in a lathe to the size of the journal or scraped to a fit by hand. The method of pouring the molten metal is clearly shown while the sectional view makes the construction and application of the mandrel clear. The same method may be used to rebabbitt main boxes except that a pair of collars will be needed for each bearing and a long mandrel used.

Testing Bearing Parallelism.—It is not possible to give other than general directions regarding the proper degree of tightening for a connecting rod bearing, but as a guide to correct adjustment it may be said that if the connecting rod cap is tightened sufficiently so the connecting rod will just about fall over from a vertical position due to the piston weight when the bolts are fully tightened up, the adjustment will be nearly correct. As previ-

ously stated, babbitt or white metal bearings can be set up more tightly than bronze, as the metal is softer and any high spots will soon be leveled down with the running of the engine. It is important that care be taken to preserve parallelism of the wrist pins and crankshafts while scraping in bearings. This can be determined in two ways. That shown at Fig. 142, B, is used when the parts are not in the engine assembly and when the connecting rod bearing is being fitted to a mandrel or arbor the same size as the crank pin. The arbor, which is finished very smooth and of uniform diameter, is placed is two V blocks, which in turn are supported by a level surface plate. An adjustable height gauge may be tried, first at one side of the wrist pin which is placed at the upper end of the connecting rod, then at the other, and any variation will be easily determined by the degree of tilting of the rod. This test may be made with the wrist pin alone, or if the piston is in place, a straight edge or spirit level may be employed. The spirit level will readily show any inclination while the straight edge is used in connection with the height gauge as indicated.

When the connecting rods are being fitted with the crankshaft in place in crankcase, and that member secured in the frame, a steel square may be used as it is reasonable to assume that the wrist pin, and consequently the piston it carries, should observe a true relation with the top of the engine base. If the piston side is at right angles with the top of the engine base it is reasonable to assume that the wrist pin and crank pin are parallel. If the piston is canted to one side or the other, it will indicate that the brasses have been scraped tapering, which would mean considerable heating and undue friction if the piston is installed in the cylinder on account of the pressure against one portion of the cylinder wall. The height gauge method shown above may be used instead of the steel square, if designed, because the top of the crank case is planed or milled true and should be parallel with the center line of the crankshaft.

On the new eight-cylinder V types of engines which are fitted on several models of 1915 cars the connecting rod design is different from that ordinarily used, as it is sometimes necessary to have two rods working from the same crank pin. The construction

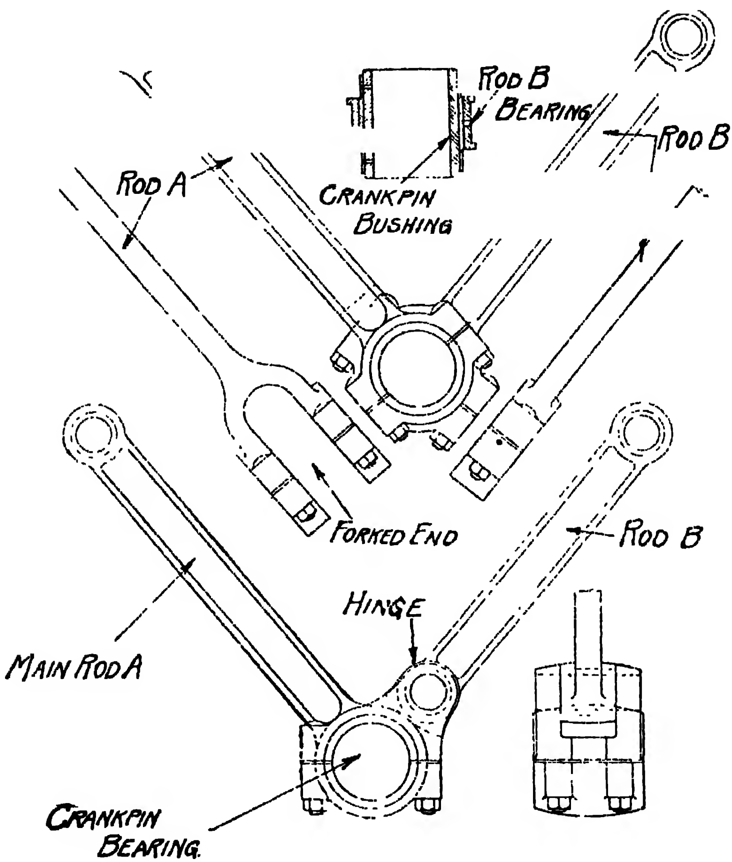


Fig. 143.—Showing Construction of Connecting Rod Needed with Eight Cylinder V Engine Unless Carried Side by Side on Crankpins.

follows very closely that used in motorcycle engines of the two-cylinder V form. Two methods of connecting rod arrangement are shown at Fig. 143. In the example at the top of the illustration, connecting rod A has a forked end which encircles the main crank pin bushing. These ends are of the usual marine type, straddling the big end of rod B, which is free to oscil-

late on the crank pin bushing. Care must be taken to fit rod A in such a manner that it will be clamped tightly around the end of the main crank pin bushing so that member will move in unison with rod A. The method outlined in the lower view uses a master or main rod A of the conventional pattern, excepting that a slotted boss is forged on one side of the connecting rod to take the lower end of rod B, which hinges on a suitable bearing pin. The crank pin bearing works in connection with main rod A just as in a four-cylinder engine, and the point to be watched

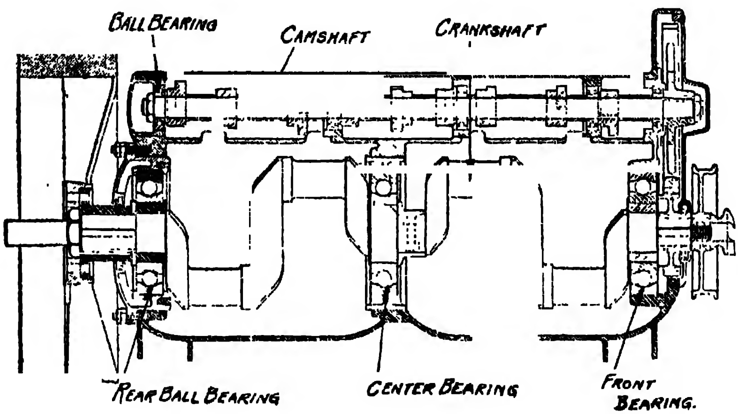


Fig. 144.—Showing Practical Application of Ball Bearings for Crankshaft and Camshaft Support.

for wear is at the hinge where rod B fastens to the main rod. The same method of fitting brasses that has been previously described in connection with the conventional forms of bearings apply just as well to the special type, though somewhat greater care will be necessary in fitting the yoke or forked end rod construction than is required with the simpler bearing subject to wear only at its inner periphery.

Ball Bearing Crankshaft.—A number of automobile engines utilize ball bearings for supporting the crankshaft as outlined at Figs. 144 and 145. While these bearings are usually selected so

a large margin of strength is present and the bearings have much greater resisting power than is needed, after the engine has been run for a time these may have loosened, and as a result are noisy in action. Ball bearings cannot be refitted as plain bearings can, and when worn it is necessary to replace them with entirely new members. This work is not difficult as these bearings are machined very accurately, and usually there is no depreciation at either the crankshaft or the bearing housing owing to all of the wear having occurred in the bearing itself. The process of replacement, there-

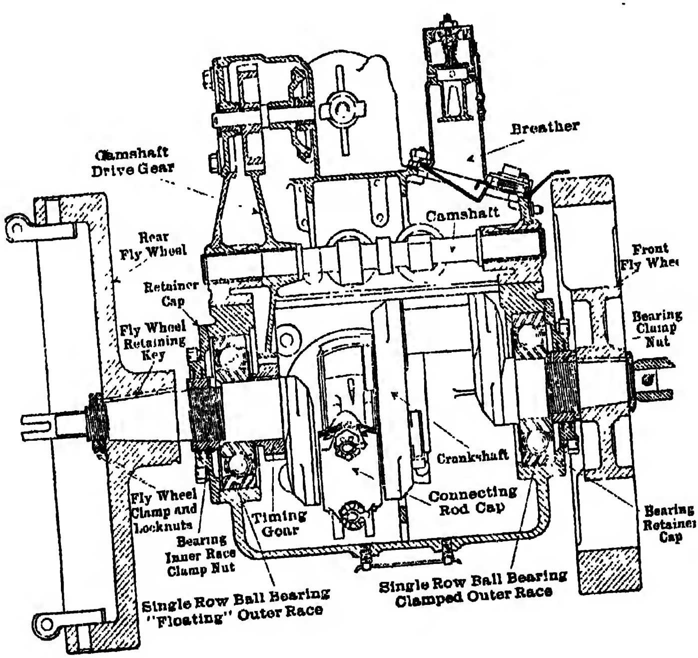


Fig. 145.—Section of Autocar Motor Crankcase Showing Ball Bearing Crankshaft.

fore, is a simple one, consisting mainly of forcing off the worn members and forcing on new ones in their place. The method of bearing retention outlined is a common one. One of the bearings, in this case the rear one, has the outer race securely held against end movement in the retaining housings, while the inner race is also tightly clamped around the crankshaft journal by means of a spacing washer and flange member tightly pressed against the bearing inner race by a suitable clamping nut. The front main bearing has only the inner race clamped. The crankshaft timing gear serves to transmit the end pressure of the nut on the front end of the shaft, which has the starting dogs or ratchet formed at one end. The idea of this is so that the pressure applied to start the engine with the hand crank will result in keeping the clamping nut tight due to the leverage of the crank. The center main bearing has a floating outer race just as the front bearing has. This means that neither of these bearings will be called upon to resist end thrust and insures that they will be subjected to only radial loads. The inner race of the center main bearing is clamped against the suitable shoulder by a slit bushing which encircles the crankshaft and which takes up the space between the bearing inner race and the crankshaft web. Most engines using ball bearings have crankshafts of the two bearing form, which means that the center bearing is eliminated and only the end bearings used. This construction has been made possible by the almost universal practice of casting four cylinders "en bloc," but the bearings are held in the same manner. The instructions given for the care and installation of ball bearings in the chapter on running gear components applies just as well to those used for crankshaft support.

Camshafts and Timing Gears.—Knocking sounds are also evident if the camshaft is loose in its bearings, and also if the cams or timing gears are loose on the shaft. The camshaft is usually supported by solid bearings of the removable bushing type, having no compensation for depreciation. If these bearings wear the only remedy is replacement with new ones. In the older makes of cars it was general practice to machine the cams separately and to secure these to the camshaft by means of taper pins or keys. These members sometimes loosened and caused noise. In event of

the cams being loose, care should be taken to use new keys or taper pins, as the case may be. If the fastening used was a pin, the hole through the camshaft will invariably be slightly oval from wear. In order to insure a tight job, the holes in cam and shaft must be reamed with the next larger size of standard taper reamer and a larger pin driven in. Another point to watch is the method of retaining the camshaft gear in place. On some engines the gear is fastened to a flange on the camshaft by retaining screws. These are not apt to become loose, but where reliance is placed on a key the camshaft gear may often be loose on its supporting member. The only remedy is to enlarge the key slot in both gear and shaft and to fit a larger retaining key.

If the camshaft is sprung or twisted it will alter the valve timing to such an extent that the smoothness of operation of the engine will be materially affected. If this condition is suspected the crankshaft may be swung on lathe centers and turned to see if it runs out and can be straightened in any of the usual form of shaft-straightening machines. The shaft may be twisted without being sprung. This can only be determined by supporting one end of the shaft in an index head and the other end on a milling machine center. The cams are then checked to see that they are separated by the proper degree of angularity. This process is one that requires a thorough knowledge of the valve timing of the engine in question, and is best done at the factory where the engine was made. The timing gears should also be examined to see if the teeth are worn enough so that considerable back lash or lost motion exists between them. This is especially important where worm or spiral gears are used. A worn timing gear not only produces noise, but it will cause the time of opening and closing of the engine valves to vary materially.

Valve Timing Methods.—Among the important factors making for efficient operation of the gas or gasoline engine, especially of the multiple cylinder type used for automobile propulsion, there is none of more importance than proper valve timing. In a four-cylinder four-cycle motor there are eight of these members, two to each cylinder, the function of the inlet valves being to permit the cylinders to fill with gas while the exhaust valves open to

clear the cylinders of the products of combustion. The inlet valve usually opens when the piston is at approximately the top of its stroke in the cylinder, or during that portion of the engine cycle where the piston is starting to go down to draw in a charge of gas. This valve is opened a period equal to the downstroke of the piston, and sometimes more, but is closed during the succeeding compression, explosion and scavenging strokes. The operation of the exhaust valve is very much the same as the inlet, except that it is opened for a longer period, starting to open before the piston has completed the downward stroke produced by the explosion and is sometimes opened slightly after the end of the return or scavenging stroke.

It is important that the valves open and close according to the timing instructions issued by the maker of the motor if maximum efficiency is to be obtained from the power plant. As the valves are operated by cams, which in turn are mounted on and driven by a shaft turning at half the crankshaft speed, the periphery of the flywheel rim may be utilized to indicate the valve timing of the motor by means of suitable marks which will register with a trammel or indicator point usually fixed back of the rear cylinder with the pointer exactly on the longitudinal center line of the engine. At first glance the marks on the flywheel may be confusing, but they are easily understood if one considers the basic operation of a four-cylinder four-cycle motor and remembers that an explosion must take place in some cylinder for every period indicated by one-half revolution of the flywheel. As the valves are usually timed to remain open a definite number of degrees measured by the crankshaft rotation, the timing may be accomplished in two ways. that previously described by following flywheel markings or by noting the travel of the piston in the cylinder with some form of depth gauge. Some manufacturers advise timing the motor by following the piston travel directly. Others make provision for this timing by marking the motor flywheel.

In marking a flywheel rim, one only needs to remember that every circle may be divided into 360 or more parts, though 360 is usually used because it indicates in degrees, whereas the smaller subdivisions, which would be in minutes and seconds, are not

needed. If the flywheel is not already marked, as might be the case if the maker followed the system of timing by piston movement directly, it is not difficult for any repairman to mark the flywheel rim if he knows the points of openings and closing of the valve as expressed in degrees of crankshaft travel. The first marks to make are the points at which two of the pistons are at the top of the stroke and two at the bottom. This is usually done by considering the cylinder nearest the radiator, or at the front of the motor No. 1 and the others in order 2, 3 and 4. The first mark made on the flywheel rim is when the piston in cylinder No. 1 is brought to the end of its stroke or toward the closed end of the cylinder. A point is prick punched on the flywheel to correspond with the pointer of the trammel or indicator. This is called "top center" cylinders 1 and 4. This may be abbreviated as "T.C.1-4," which is very easily indicated on the iron rim of the flywheel with ordinary steel letter stamps. The flywheel is then turned over a half revolution until the piston in Number 1 cylinder is at the bottom of its stroke. Another point is then indicated on the flywheel and this is marked "B.C.1-4" which is an abbreviation for "bottom center," cylinders 1 and 4. If, for example the inlet valve in number 1 cylinder opens fifteen degrees after top center a distance is measured off on the flywheel rim equal to a crank shaft travel of 15 degrees. A line is then scribed across the face of the flywheel and this is marked "inlet opens" 1 and 4. If the inlet valve closed 20 degrees after bottom center the flywheel is rotated half a turn until the bottom center line registers with the trammel. A suitable distance is then measured off on the flywheel face from that point that would be equal to a travel of 20 degrees on a circle represented by the circumference of the flywheel.

The rule for determining the amount of space to allow for a degree is not a difficult one to apply in practice. It is merely necessary to multiply the diameter of the flywheel in inches by a constant value, 3.1416, which remains the same regardless of diameter of the flywheel, to obtain the circumference of the flywheel in inches. This product is divided by 360, which gives the amount of space to measure off on the flywheel rim for each de-

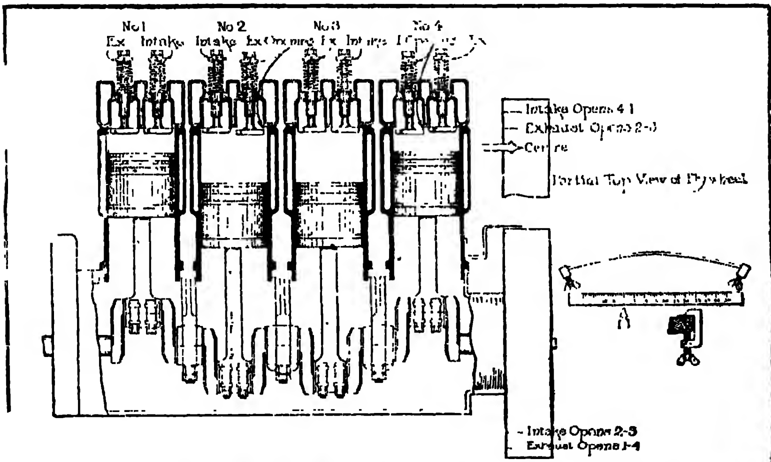
gree. While the figuring is not difficult, the result may be very quickly arrived at by reference to the accompanying table of angles and corresponding arcs which has been compiled by A. C. Woodbury and printed in the Horseless Age. A conversion table is also appended which will be of value inasmuch as it permits the conversion of hundredths of an inch to sixty-fourths of an inch, which subdivision is more apt to be found on standard flexible scales used by American machinists.

After having marked the flywheel for the inlet valve, the next operation is to indicate the points of opening and closing for the exhaust valve of No. 1 cylinder. As a rule, the exhaust valve opens about 45 degrees ahead of the bottom center position of the piston when that member is impelled downward by the force of the explosion. Following the closing of the inlet valve, nearly two strokes of the piston takes place before the exhaust opens, one being the stroke corresponding to the compression of the gas while the other corresponds to the downward travel of the piston due to explosion pressure. The exhaust valve usually closes a few degrees before the inlet opens, though on some engines the exhaust may not be fully closed before the intake starts to open.

A cross section view of a four-cylinder engine with the valves located in the combustion heads is shown at Fig. 146, which also indicates the method employed of marking the flywheel and gives the relation of the various strokes for the two most commonly used firing orders employed with four-cylinder motors. The explosions do not occur in each cylinder in the same sequence as the cylinders are numbered. An explosion in cylinder No. 1 is followed by one in No. 2, then by one in No. 4, and lastly by one in No. 3, according to one method. In the other the firing order is 1—3—4—2. In other words, the explosions must follow each other in cylinders 1 and 2 or in cylinders 3 and 4, because in these one piston is up while the other is down.

Considering the firing order first named, if an explosion is taking place in cylinder No. 1 driving the piston downward, the piston in cylinder No. 2 is compressing a charge as it is moving upward, that in No. 3, which is moving in the same direction as the piston in No. 2, is expelling the burnt gas, and the piston in

. 4, which is moving down or in the same direction as piston . 1, is drawing in a charge of gas. At the completion of the xplosion stroke in cylinder No. 1 the positions of the pistons is the reverse to that shown in the illustration, i.e., pistons in No. 1 and No. 4 are at the open end of the cylinder, whereas those in No. 2 and No. 3 are at the top or closed end.

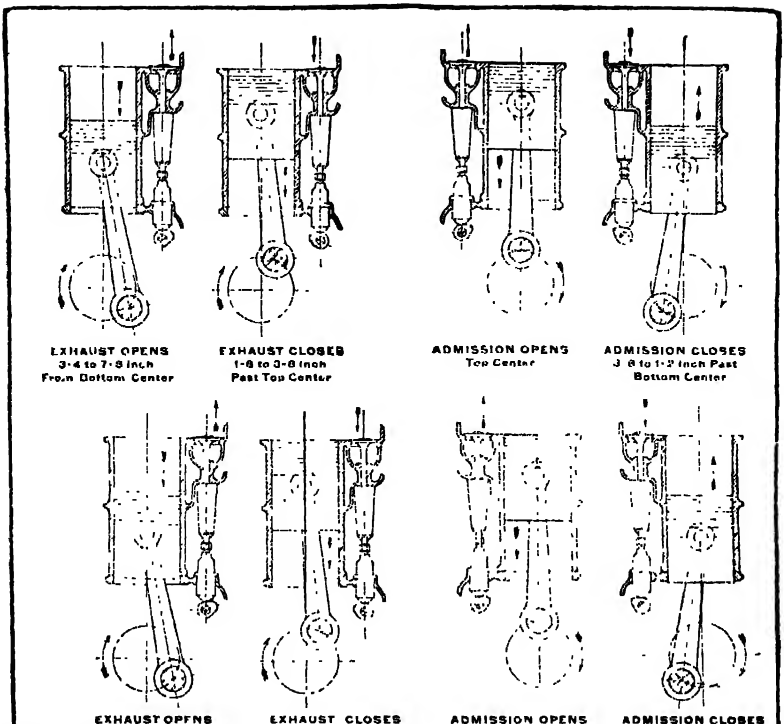


How Valves Are Timed and Tappets Adjusted by Utilizing the Markings on the Flywheel.

FIRING ORDER 1-2-4-3.				FIRING ORDER 1-3-4-2.			
Cylinder 1	Cylinder 2	Cylinder 3	Cylinder 4	Cylinder 1	Cylinder 2	Cylinder 3	Cylinder 4
1—Firing	Compression	Exhaust	Suction	1—Firing	Exhaust	Compression	Suction
2—Exhaust	Firing	Suction	Compression	2—Exhaust	Suction	Firing	Compression
3—Suction	Exhaust	Compression	Firing	3—Suction	Compression	Exhaust	Firing
4—Compression	Suction	Firing	Exhaust	4—Compression	Firing	Suction	Exhaust

Fig. 146.—Explaining Method of Timing Valves and Marking Flywheel of Four Cylinder Motor.

When piston No. 1 starts to go up again it will be f[illegible]g out the burnt gas due to the previous explosion. That in No. 2, which reached the top end of the stroke just after compressing the rge, is subjected to the explosion; that in No. 3, which moves the same direction as piston No. 2, and which has just cleared the burnt gas, is drawing in a fresh charge, while piston No. 4 moving toward the top of the cylinder, compressing the gas [illegible]ed during the preceding downward stroke. The remainder



	EXHAUST OPENS	EXHAUST CLOSES	ADMISSION OPENS	ADMISSION CLOSES
1911 "48"	11-16 Before bottom center	[illegible] Past top center	Top center	[illegible] Past bottom center
1913 "48"	[illegible] Before bottom center	[illegible] Past top center	Top center	[illegible] Past bottom center
1913 "18"	[illegible] Before bottom center	[illegible] Past top center	Top center	[illegible] Past bottom center

Fig. 147.—Instructions Given by the Locomobile Company for Valve Timing of its Various Early Models.

of the operations may be readily followed by the reader by studying the illustrations and the explanatory context.

At Fig. 147 the system of valve timing employed on several models of the Locomobile cars is clearly outlined. At the top the points of opening and closing of the valves in the Locomobile Model L, as measured by piston travel, are depicted, while the bottom series shows the timing of the models R and M for a period

of years. It will be apparent that it would not be difficult to measure the piston travel by inserting a suitable depth gauge through a petcock at the top of the cylinder, so a rod or wire could be employed to follow the piston movement.

At Fig. 148 the valve timing of the 1915 Overland motor is outlined, this showing the method of indicating the points on the flywheel rim, and also the amount of travel of the crankshaft to conform to the number of degrees opening and closing of the valve. The marks on the flywheel and their meaning follows:

1-4 Up means: cylinders 1 and 4 are in their uppermost position.
2-3 Up means: cylinders 2 and 3 are in their uppermost position.
1-4 I O means: inlet valve of cylinder 1 or 4 opens.
1-4 I C means: inlet valve of cylinder 1 or 4 closes.
1-4 E O means: exhaust valve of cylinder 1 or 4 opens.
1-4 E C means: exhaust valve of cylinder 1 or 4 closes.
2-3 I O means: inlet valve of cylinder 2 or 3 opens.
2-3 I C means: inlet valve of cylinder 2 or 3 closes.
2-3 E O means: exhaust valve of cylinder 2 or 3 opens.
2-3 E C means: exhaust valve of cylinder 2 or 3 closes.

To determine when the setting of the valves is correct proceed as follows, beginning with cylinder No. 1: First, open the priming cocks over all exhaust valves to relieve the compression and to make flywheel rotation easier. Second, turn the flywheel to the left until the mark 1-4 Up is in line with the punched guide mark on No. 4 cylinder. Pistons No. 1 and No. 4 are now at their highest points, or on upper dead center. About 1¼ inch to the right of the mark one will notice another indication, 1-4 I O. Turn the flywheel to the left until this mark is lined up with the punch mark on cylinder. At this point the inlet valve of either cylinder No. 1 or cylinder No. 4 should begin to lift. If the lift should occur in cylinder No. 4, turn the flywheel one complete revolution until the marks 1-4 I O again appear on top and in line with the guide marks. Now feel of the inlet valve lift plunger of cylinder No. 1, which should be in contact with the inlet valve stem, and further rotation of the flywheel to the left should begin to produce a lift of the inlet valve, which may be observed by watching the upward movement of the valve stem. Third, to de-

termine the closing point of the same inlet valve turn the flywheel a little more than half a revolution until the mark 1-4 1 C appears on top and registers with the punch mark on the cylinder. With the flywheel in this position the inlet valve should be closed, and after very slight movement of the flywheel to the left there should be enough space between the top of the valve plunger and the inlet

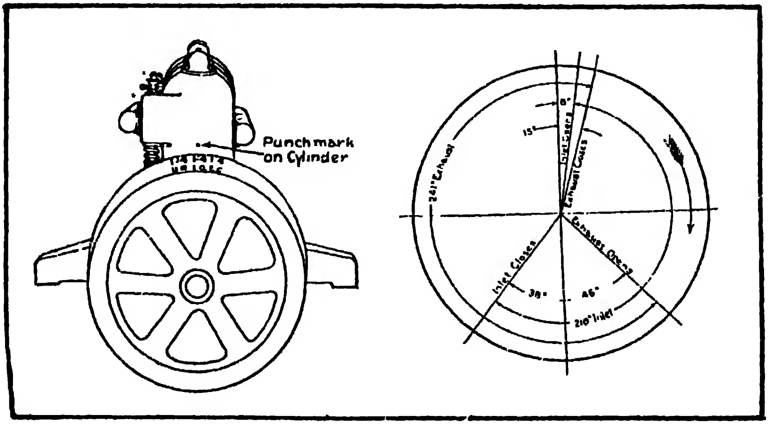


Fig. 148.—How the Overland Four Cylinder Motor Valves are Timed.

valve stem to insert a thin visiting card. At the Overland factory this space is measured by a gauge exactly twelve thousandths of an inch (.012) thick; this clearance is necessary to compensate for the expansion of the valve stem when it becomes hot during the operation of the engine. The exhaust valve opening in No. 1 cylinder is then gone over in the same manner. After the point where the inlet valve closes the flywheel is turned half a turn until the mark 1-4 Up comes to the top. Turn the flywheel to the left until a mark indicated by 1-4 E. O. registers with the punch mark in the cylinder. To determine the point of exhaust valve closing turn the flywheel to the left for a space equal to 241 degrees measured on the flywheel rim where a mark will be found indicating the point of exhaust valve closing, which will be 1-4 E. C. In order to enable the repairman to judge the amount of distance

measured on the flywheel circumference corresponding to the number of degrees valve opening the following tabulation is given:

	Model 69	Model 71
Diameter of flywheel	17 in.	18 in.
Inlet valve opens late	$1\frac{3}{16}$	$1\frac{1}{4}$
Inlet valve closes late	$5\frac{21}{32}$	$5\frac{31}{32}$
Exhaust valve opens early	$6\frac{27}{32}$	$7\frac{15}{64}$
Exhaust valve closes late	$2\frac{15}{64}$	$2\frac{23}{64}$

The same instructions apply to 1915 four-cylinder motors.

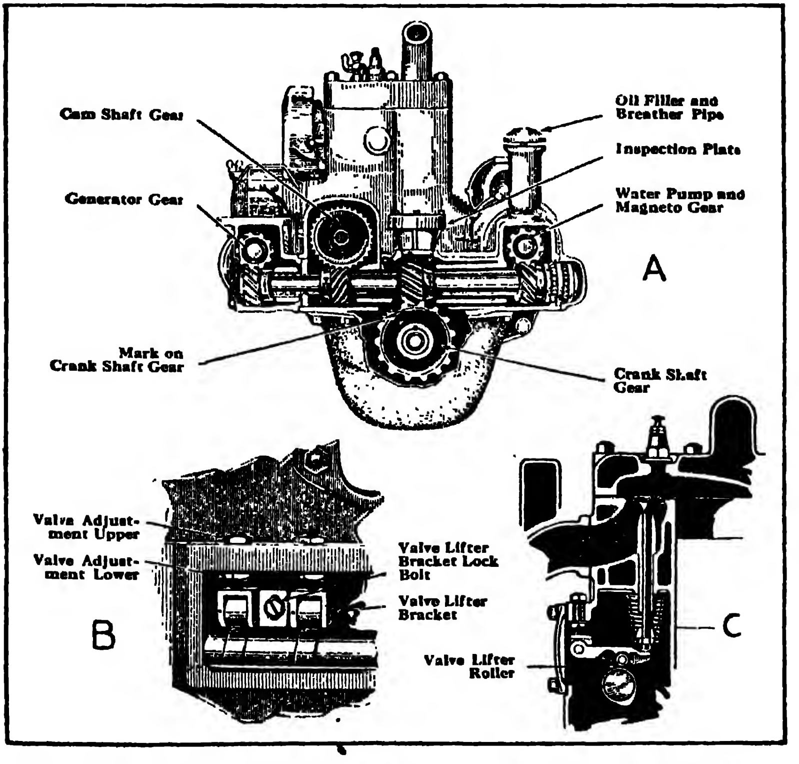


Fig. 149.—Method of Timing Valves of Overland Six Cylinder Motor and Adjusting Valve Gear.

Remeshing Overland Model 82 Time Gears.—A cross shaft on front of the motor operates the generator and pump shaft. This shaft is driven by a bronze gear keyed to the front end of the crankshaft. The gear at the extreme left of the cross shaft (Fig. 149) or right hand side of the motor drives the generator shaft. The second gear from the left of the illustration drives the camshaft. The gear at the right of the cross shaft drives the pump and magneto shaft which, like the cam and generator shaft, runs parallel to the crankshaft. When these have been taken apart and are to be reassembled, follow these directions: Turn the flywheel until pistons 1 and 6 are on upper dead center, with No. 1 just completing its compression stroke and ready to fire. On keying the driving gear to the crankshaft, make sure that the straight mark on the top of the gear is lined up with the bottom face of the cylinder casting.

Through the inspection plate you will notice a straight mark lengthwise of the cross shaft. This mark must line up with a corresponding mark on the face of the inspection plate. Lining up the shaft, of course, automatically brings the four gears keyed on to the shaft in their proper positions. Now it is only necessary to assemble the three driven gears so that the arrow punched on the face line with the corresponding mark on the housing.

Timing the Valves.—This, too, is an operation which should be undertaken with caution and carried out with accuracy, and by a person competent to do such work. The rim of the flywheel bears at various points the following marks:

1-6 D-C means: pistons of cylinders 1 and 6 are in their utmost position.
2-5 D-C means: pistons of cylinders 2 and 5 are in their utmost position.
3-4 D-C means: pistons of cylinders 3 and 4 are in their utmost position.
1-6 I-O means: inlet valve of cylinder 1 or 6 opens.
1-6 I-C means: inlet valve of cylinder 1 or 6 closes.
1-6 E-O means: exhaust valve of cylinder 1 or 6 opens.
1-6 E-C means: exhaust valve of cylinder 1 or 6 closes.
2-5 I-O means: inlet valve of cylinder 2 or 5 opens.
2-5 I-C means: inlet valve of cylinder 2 or 5 closes.
2-5 E-O means: exhaust valve of cylinder 2 or 5 opens.
2-5 E-C means: exhaust valve of cylinder 2 or 5 closes.

3-4 I-O means: inlet valve of cylinder 3 or 4 opens.
3-4 I-C means: inlet valve of cylinder 3 or 4 closes.
3-4 E-O means: exhaust valve of cylinder 3 or 4 opens.
3-4 E-C means: exhaust valve of cylinder 3 or 4 closes.

The motor cylinders are numbered 1, 2, 3, 4, 5, 6, number 1 being the cylinder near the radiator and number 6 the nearest the dash. Cylinder number 1 fires first, number 5 next, then numbers 3 and 6, then 2 and 4. The timing of the valves is, perhaps, best understood by reference to the diagram. It will be seen that the intake valve opens when the flywheel is 7° 54′ past upper dead center and closes when it is 30° 6′ past the lower dead center. The exhaust valve opens 41° 2′ before the lower dead center and closes again 3° 51′ past upper dead center; thus the inlet valve opens and closes late, whereas the exhaust valve opens early and closes late.

The flywheel being 15½ inches in diameter, the following table gives the measurements in inches of the valve operation when laid out on the rim of the flywheel:

Diameter of flywheel	15½ inch
Inlet valve opens late	1.07 inch
Inlet valve closes late	4.07 inch
Exhaust valve opens early	5.59 inch
Exhaust valve closes late	.52 inch

To determine whether setting of the valves is correct, proceed as follows, beginning with cylinder number 1: Open the priming cocks over all exhaust valves, to make the turning of the flywheel easier. Turn the flywheel to the left until the mark 1-6 D-C is in line with the guide mark on number 6 cylinder. Now pistons 1 and 6 are at their highest points in their cylinders, or on upper dead center. About 1.07 inches to the right of mark 1-6 D-C you will notice the mark 1-6 I-O. Turn the flywheel to the left until this mark is lined up with the guide mark on the motor. At this point the inlet valve of either cylinder 1 or cylinder 6 should begin to lift. If the lift should occur in cylinder 6, turn the flywheel one complete revolution, until the mark 1-6 I-O again appears on top and in line with the guide

mark. Now watch or feel the inlet valve stem of cylinder 1; it should just begin to lift from its seat.

To determine the closing point of the same inlet valve, turn the flywheel a little more than a half revolution, until the mark 1-6 I-C appears on top. With the flywheel in its position, the inlet valve should be closed and there should be just enough space between the top of the valve-lifter and the valve stem that a thin visiting card can be placed between them. At the factory stem and lifter are set so that the distance between them is exactly four thousandths of an inch; this clearance is necessary to compensate for the expansion of the valve stem when it becomes hot during the operation of the engine.

If adjustment is necessary, loosen the lock-nut on the top of the valve lifter bracket and screw the lower nut up and down, as shown in B, Fig. 149. If the play between valve lifter and valve stem is too great, the result will be noisy operation; if the adjustment is too close, the valve may be prevented from seating fully. Next, test the exhaust valve, again bringing 1-6 D-C to the top, and turning the flywheel to the left until the mark 1-6 E-C appears in line with the guide. After you have tested the closing of the exhaust valve of cylinder number 1, test its opening by revolving the flywheel until the mark 1-6 E-O comes to the top. Then go carefully over the valves of cylinders numbers 6, 2 and 5 and 3 and 4. A slight variation of the flywheel markings to the right or left of the guide mark is permissible, but it should not be greater than a quarter of an inch.

There is hardly a repair shop in the world that will not have occasion to time the valves of a Ford motor. The firing order is 1—2—4—3 and the point of valve openings are clearly indicated in diagrams at Fig. 150. These show the points as measured directly by the piston travel and need no further explanation.

Marking Offset Cylinder Motor.—The instructions given for marking flywheels apply specifically to those engines in which the center lines of the cylinder and crankshaft coincide. If there is no offset the flywheel is marked from upper and lower dead centers, which also indicate the top and bottom positions of the pistons in the cylinders. With an offset crankshaft, the flywheel

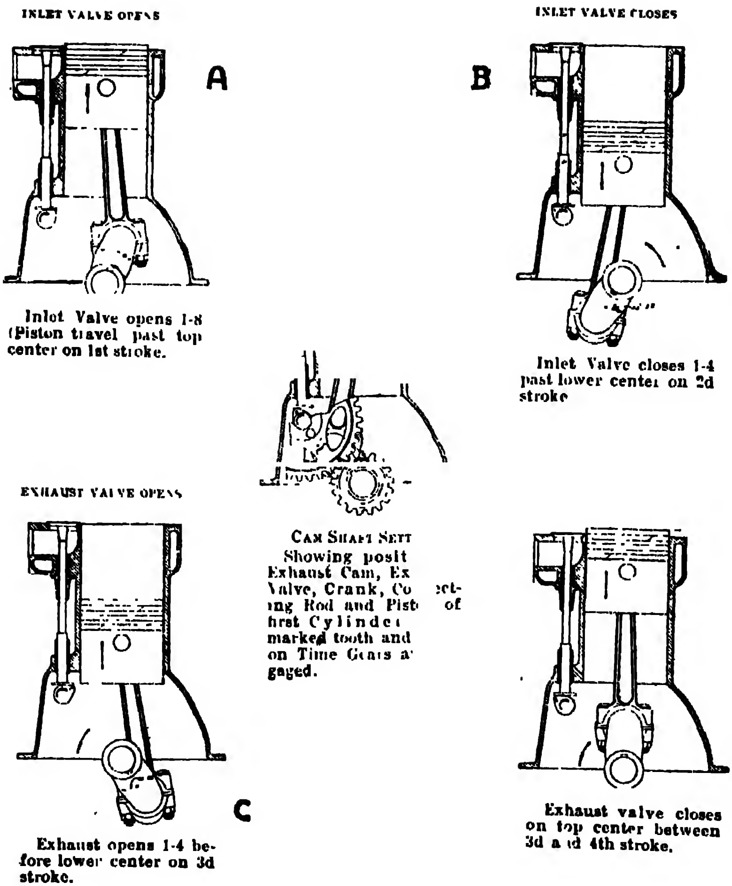


Fig. 150.—Methods of Timing the Ford Four Cylinder Motor.

is marked at the upper vertical point by the angles laid off from that position of the piston, connecting rod and crankshaft which brings the three centers into line, i.e., the piston pin center, the crank pin center and the center of the crankshaft bearing. The reason for this is that with the piston at its highest point as

indicated by the usual method of finding upper center by setting the connecting rod vertically in the upper position, a slightly further movement of the crank which will bring the three centers into line will raise it a small amount further, this latter being the true point of upper dead center. Similarly with the lower center when the connecting rod is at its lowest point and starts to rise slightly, the piston is not at its lowest point and the movement past center, until the three center points mentioned come into line, will continue to draw the piston downward a slight, though measurable, amount. In the illustration, Fig. 152, the four stages of timing off-set engines are shown. The proportions of this motor have been exaggerated to some extent to clearly bring out the points involved. The cycle of the engine is followed through by the diagrams in proper

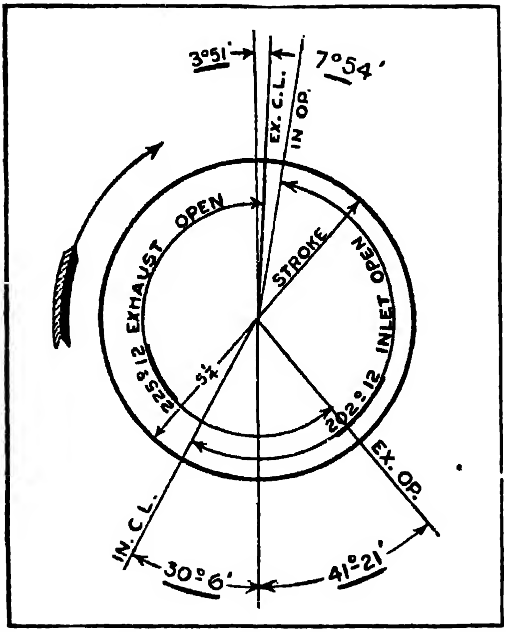


Fig. 151.—Diagram Showing Flywheel Marking on Overland Six Cylinder Motor.

sequence, this being inlet opening, inlet closing, exhaust opening and exhaust closing. In these diagrams the timing used is: Inlet opens at 8 degrees past the upper center; inlet closes at 26 degrees past the lower center, making the total inlet opening 198 degrees; exhaust opens at 46 degrees before lower center, exhaust closes at 5 degrees past upper center, making the total exhaust opening 231 degrees. If the engine timing differs from this and the flywheel is not marked, with the points of opening

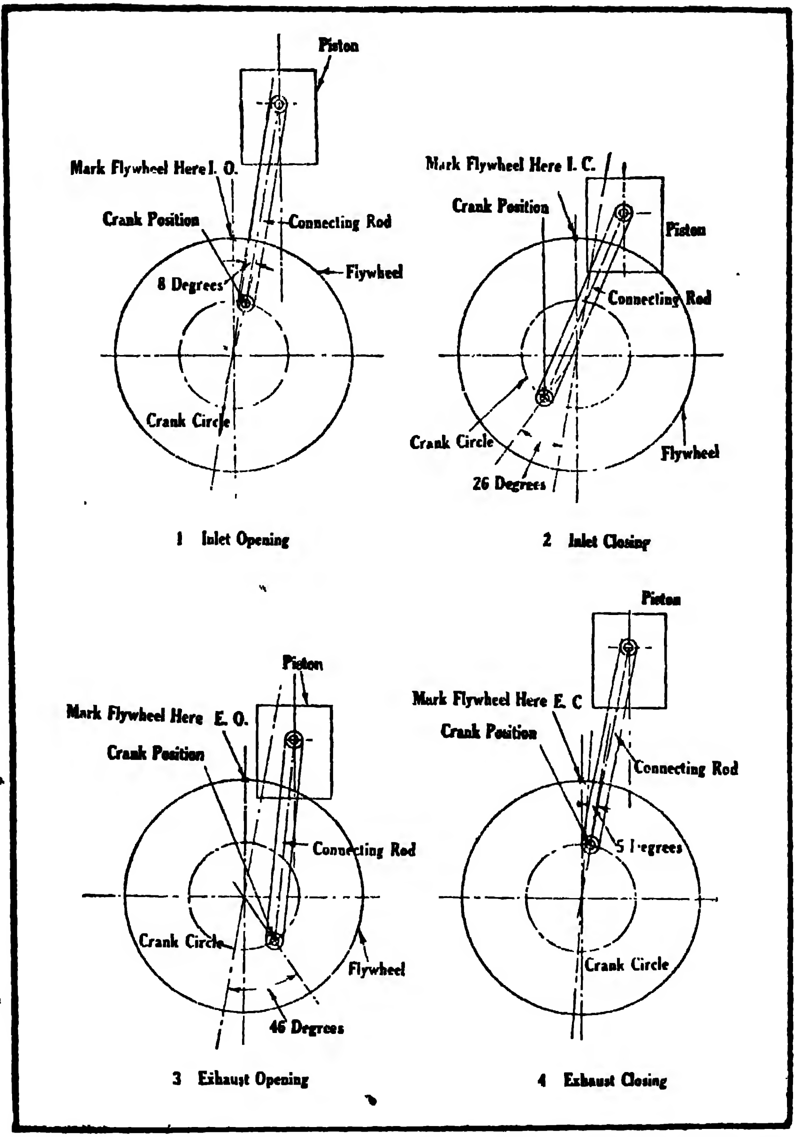


Fig. 152.—How to Mark Flywheels of Engines Having Offset Cylinders.

and closing given, it will not be difficult to mark the flywheel rim, though this is a job that must be carefully done. To simplify the explanation, we will assume that the motor timing is the same as indicated. The method of procedure is as follows: First, place the engine in a suitable position to work on and remove the lower half of the crankcase. Turn the crankshaft over slowly until the upper end of the connecting rod reaches the top point, then turn still more slowly, until the three centers are brought into line. This will be a somewhat difficult job to handle, but with care, assisted by the more usual method of placing a pointer in the top of the cylinder, resting on the piston, and moving up and down with the latter, this can be accomplished. Having the center, lay a straight edge across the crankcase lower edge, and set a protractor or other angle measuring device to the exact angle between this and the cheeks of the crankshaft. Now, take this protractor off, note the angle, and then add to this the angle of the inlet opening, eight degrees as above. Set this back on the straight edge and turn the crank until the cheeks coincide with the new setting of the protractors. Then mark the upper point of the flywheel with the initial letters I O, to indicate inlet opening. It is well to mark this at the time the work is done with prick punches which can be remedied afterward, scribing a line clear across the flywheel and then putting in the letters or the full words if desired.

Find the following lower dead center and mark the flywheel for that in the same manner. Then, nearly a full turn is necessary before the next lower center, from which the angle of the exhaust opening must be subtracted, this calling for a backward movement. No trouble need be experienced in the final exhaust closure point. In the sketch the marking is indicated to go on the center of the flywheel, that is, directly above the center line of the crankshaft. This is not necessary, the marks may be put anywhere desired, on the cylinder center line or elsewhere. A pointer of sheet metal should be made and fastened on the engine case somewhere, preferably under the nuts of the rear cylinder bolts, so as to point to the marks.

Two typical valve timing diagrams, one for a four cylinder engine having a flywheel diameter of 15¾ inches, the other of a six

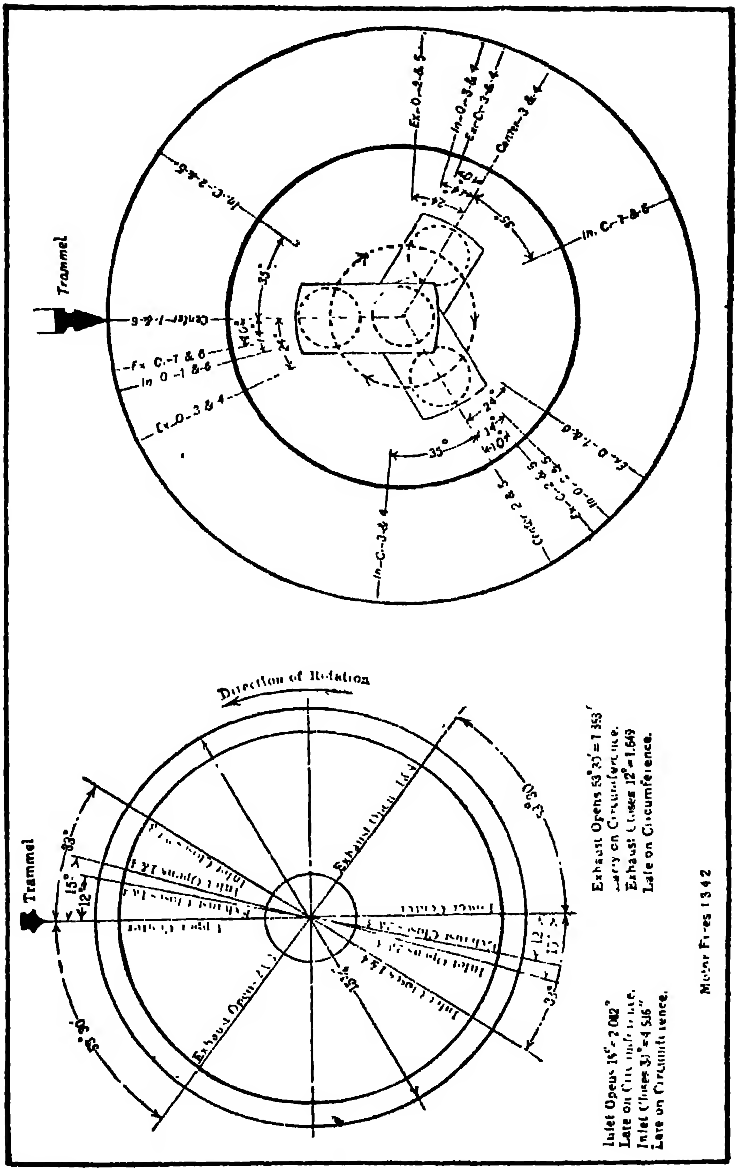


Fig. 153.—Typical Valve Timing Diagrams for Four and Six Cylinder Engines.

cylinder engine are given at Fig. 153. In the diagram at the left, which is that of a four cylinder motor having a firing order of 1—3—4—2, the points of valve opening and closing are not only indicated in degrees but also by the equivalent dimensions measured on the flywheel periphery. In the six cylinder engine diagram shown at the right the points are indicated measured in degrees.

In studying the table presented, it should be remembered that there are many conditions upon which valve timing depends, and a formula correct for one motor would not necessarily be satisfactory for another of the same size. In all cases, the inlet valve opens after the piston has reached the end of its exhaust stroke, the lag depending upon the size of the valve, shape of cam and motor speed desired. Most designers do not open the inlet valve until the exhaust is fully closed, but there are some who allow the valves to overlap; that is, the inlet valve starts to open before the exhaust is fully closed. It should be remembered that exhaust closing and inlet opening occur approximately after that point in the cycle where the piston reaches the end of its second up stroke. The inlet valve closes after the bottom of the suction stroke is reached, good practice being a lag of between 30 and 40 degrees crank travel. The exhaust valve opens before the piston reaches the end of its down stroke under the influence of the explosion. The lead may be as high as 60 degrees crank travel before center, but this is an extreme case. Good average practice is covered in the range between 40 and 45 degrees lead.

The reason for having the exhaust valve closing and inlet valve opening overlap is that this takes advantage of the momentum of the exhaust gas and results in clearing the cylinder more positively than if the valve closed absolutely on center. During the final period of valve closing but little space is present for the escape of gases. If the valve closed positively on upper dead center, the area of the port or passage would be small for an appreciable upward movement of the piston when it neared the top of its stroke, and more inert gas would be retained in the cylinder than if the valve was closed after the piston starts down on the intake stroke.

The following table outlines the valve timing of a number of standard American automobile motors.

VALVE TIMING OF SOME TYPICAL AMERICAN CARS
FROM S.A.E. DATA SHEET, No. 53, VOL. I

Car	Intake Opens Deg. Min.	Intake Closes Deg. Min.	Exhaust Opens Deg. Min.	Exhaust Closes Deg. Min.
Abbott, 34–40	11.30	49.12	45.48	11.30
Abbott, 44–50	17.53	29 25	42.36	8 20
Cadillac, 1914	4.20 to 14.20	38 26	31.34	7.00
Case, 40	13 00	30.00	50 00	13.00
Chalmers	12.00	33.00	55.00	12.00
Chandler Six	14.00	39.00	49.30	12.00
Chevrolet C	13 00	49 00	47 00	9.00
Chevrolet H-2, H-4	16 48	54.08	27.13	14.06
Franklin, M No. 4	8.00	33 00	51.30	17 00
Haynes, 26–27	5.00	35.00	47.00	2.00
Haynes, 28	5.00	35.00	37.00	2.00
Hupmobile, 32	21.00	28 00	46.00	16.00
Jackson, 1914	15 00	38 00	45.00	10.00
Jeffery, 6-96	18.00	46 00	47.00	15.00
Jeffery, 4-93	18.00	46.00	47.00	15.00
King B	9 44	30 38	32.10	5.00
Lewis Six	15 00	30.00	45.00	5.00
Lyons-Knight	10.00	40 00	60.00	on
Maxwell, 4 35	5.00	40.00	35.00	on
Maxwell, 4-25	6.00	32.00	43.00	6.00
Moon, Six 50	10.00	28 00	40 00	2.30
Moon, Four 42	14.00	24.00	31.00	21.00
Oldsmobile, 54	15.00	38.00	45.00	10.00
Paige Detroit, 36	9.40	32.30	41.50	11.40
Paige Detroit, 25	9.40	32 25	40.30	12.00
Pathfinder Little 6	10.00	28.00	40.00	2.30
Reo	18.00	36.00	53.30	14.00
Speedwell, A.B.C	10.00	28.00	40.00	2.30
Velie	7.00	36.00	43.00	12.00
Vulcan	15.00	30 00	45 00	10.00

When the space between the valve stem and the valve lifter is more than it should be there are two methods of compensating for this depreciation. On many small motors no adjustment is provided between the valve stem and the valve stem plunger. The makers of the Ford car advise drawing the valve stems out until the proper space exists between the push rod and the stem. It is important when drawing out the stem or lengthening it not to bend the valve stem, as this will result in the valves sticking, or in any event the bore of the valve stem guide in the cylinder will be worn unevenly. The clearance between the pushrod and the valve

stem should never be greater than $\frac{1}{32}$-inch nor less than $\frac{1}{64}$-inch. If too much clearance is present the valves will open late and close early. If the clearance is less than the minimum there is danger of the valve remaining partially open all of the time because the valve stem lengthens, due to expansion produced by the heat of the explosion. When it is necessary to draw down a valve stem this should be done by peening it for about $\frac{3}{4}$-inch above the pinhole or key slot.

It is not a difficult matter to set the clearance exactly as it should be on those types of engines provided with an adjustment screw which may be raised or lowered in the valve plunger or in forms having fiber inserts in the top of the valve plunger. These inserts are utilized to silence the valve action and may be easily removed and replaced with new ones when worn. A simple and cheap accessory that can be obtained on the open market can be used to adjust the clearance on Ford and similar type motors. This consists of a number of stamped steel cups that can be pushed on the lower portion of the valve stem and a number of thin steel washers to be interposed inside of the cup and between the bottom of that member and the end of the valve stem to regulate the clearance as desired.

Sleeve Valve Motors.—A number of automobile manufacturers have adopted the Knight sleeve valve motor as a power plant. The same instructions that have been given regarding the time of opening and closing of the valves of other motors also apply to this form in a limited degree. The only possibility of losing the timing on the sleeve valve motor, which is shown in section at Figs. 154 and 155, is by faulty setting of the sleeve operating crankshaft, in its relation to the main crankshaft. If the timing is altered by depreciation of the bearing in the sleeve operating links they may be refitted; the lower or rotating bearings which would be more apt to wear than the upper or oscillating bearings, are of the same marine pattern as is generally used in the main connecting rod. This means that any depreciation may be remedied by fitting the bearing caps closer to the connecting rod and scraping or reaming to fit.

In order to show clearly the appearance of the various parts

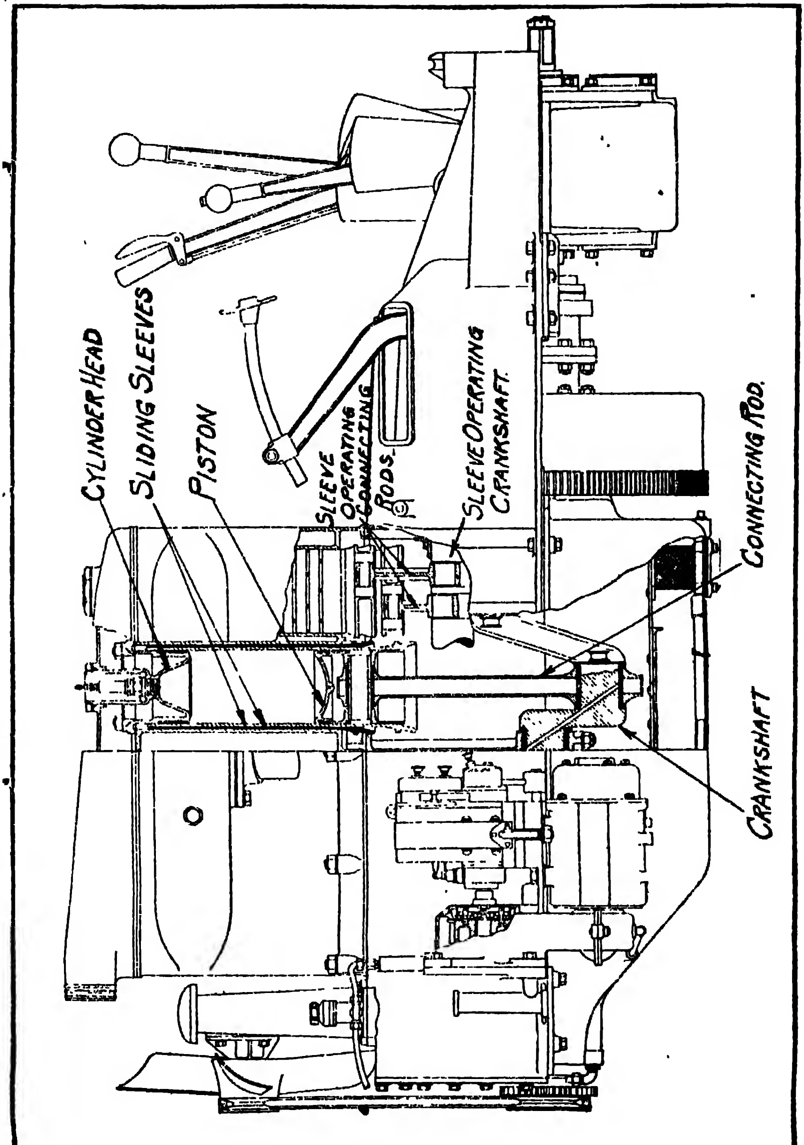


Fig. 154.—Sectional View of Knight System Sliding Sleeve Valve Motor

of the sleeve valve mechanism the views at Fig. 156 are presented. At A, the cylinder heads which have just been removed from the cylinder block B, are depicted. The connecting rod, piston and the two sleeve valves in one assembly just as it is removed from the cylinder interior is shown at C. The piston and connecting rod removed from the interior of the inside or long sleeve is shown at B, the inside or long sleeve is outlined at E, and the short sleeve is shown at F. It will be apparent that the gas passages which are in the form of slots cut into the upper portion of the sleeve walls are not apt to change in size except the very small amount due to the deposit of carbon in the port openings. Obviously they may be restored to full size by scraping away that material.

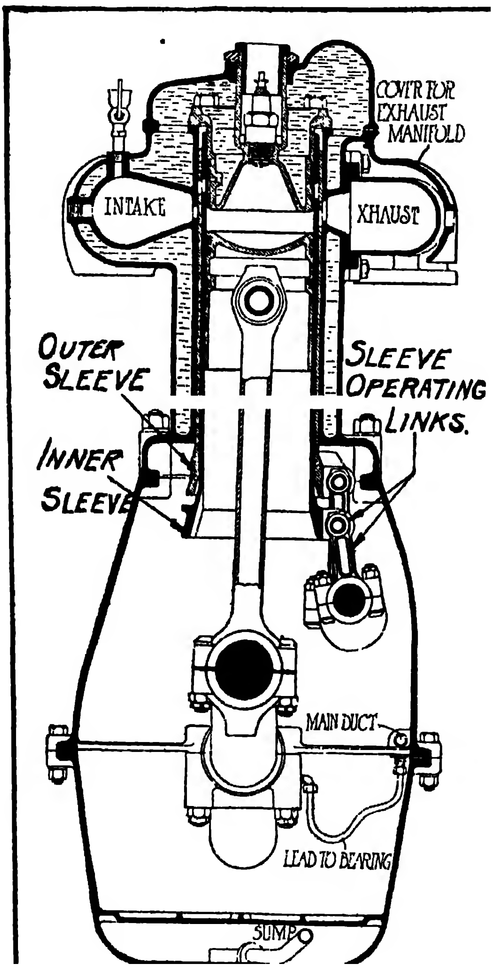


Fig. 155.—Showing Application and Method of Operation of Sliding Sleeve Valve.

The illustrations at Fig. 157 will show clearly the relation of the two sleeves and the cranks operating them, while the series of views at the right will show the way the various ports register

to provide a clear passage for the ingress or egress of the gases. At A, the piston is shown at top center, the exhaust ports have just closed and the inlet ports are just about to register and permit the gas to flow into the cylinder as the piston descends on its suction

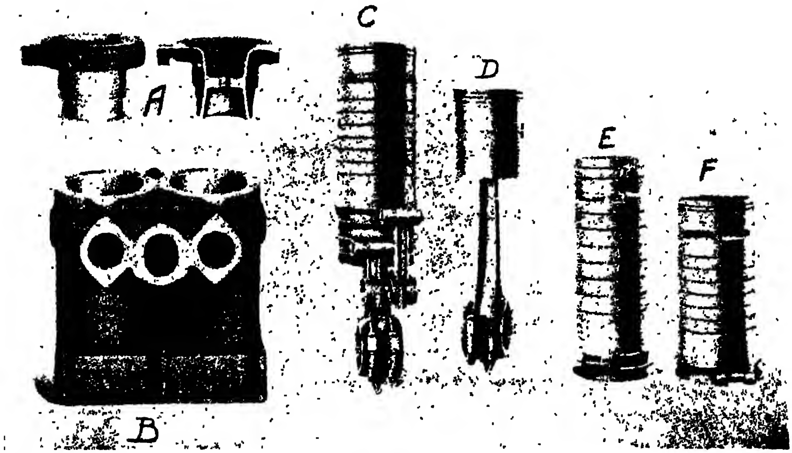


Fig. 156.—Parts of Sleeve Valve Cylinder Assembly.

stroke. At B, the piston is seen nearing the end of its stroke and the inlet port is fully open. The exhaust port is completely closed. At C, is shown the end of the intake stroke with the inlet ports just closing. The view at D, shows the piston at the end of its compression stroke with both inlet and exhaust ports closed. At E, the piston has gone down the greater portion of its power stroke and the exhaust openings in the inlet and outer sleeves are just beginning to meet and register with the exhaust outlet port in the cylinder. At F, the exhaust port is about half open, at G, the exhaust port is fully open. The piston and crank position at H, indicate the closing of the exhaust port. The inner and outer sleeves therefore, cannot vary in timing which is determined by the disposition of the throws on the sleeve operating crankshaft. If for any reason the proper relation of rotation between the main crankshaft and the member operating the sleeve valves is lost one may begin at cylinder No. 1 and time the engine in somewhat the same

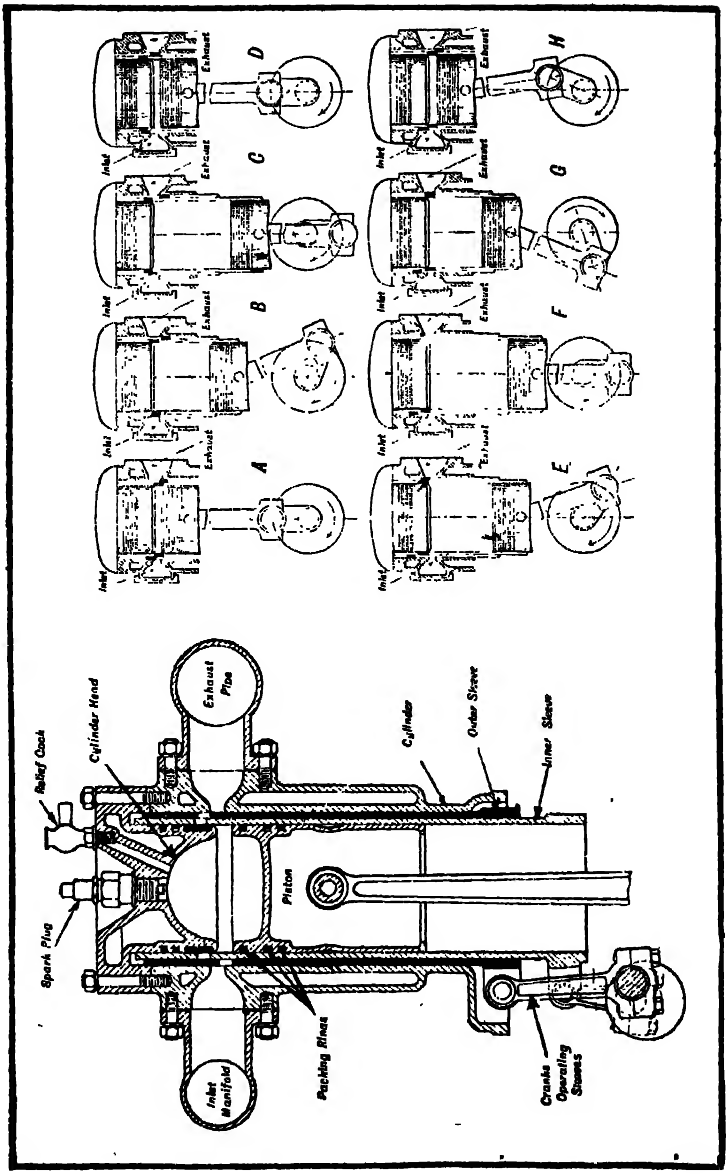


Fig. 157.—Operation of Knight Slide Valve Motor Showing Action of Sleeves for Opening and Closing Cylinder Ports.

manner as the poppet valve motor is timed. The instructions given for setting the sleeve valve of the Lyons-Knight motor are: the intake opens 10 degrees after top dead center and closes 40 degrees after the bottom dead center. The exhaust valve opens 60 degrees crank travel before the piston reaches the end of its power stroke and closes on dead center.

One peculiar point about the sleeve valve motor in which it differs radically from the poppet valve type is that the carbon deposits which are very detrimental to proper poppet valve operation are said to be actually beneficial to the operation of sleeve valves because the carbon on the sleeves has a certain lubricating value. Instead of endeavoring to prevent carbon accumulation all sorts of expedients are tried in the various plants where sleeve valve motors are manufactured to assist carbon accumulation. Mr. Charles Y. Knight the inventor of this type of motor writes as follows regarding the formation and utility of carbon in sleeve valve motor operation:

"Providence seems in the case of the sleeve valve to deposit the carbon just where it is required, rectifying any small errors in clearances or adjustments or small ring leakages which may have crept into the construction. And the user is advised to be most careful about its removal—not to interfere with the deposit unless through some extraordinary conditions the character of the accumulation partakes of the scale-like formation which upon severe use of the motor becomes incandescent, as shown by its brown color and projecting scale-like form. Happily, such scale is seldom encountered, and when it may have formed as a result of the cause described, the user is advised to remove it, not with the use of a sharp-edged metal tool, but by employing a coarse, rough piece of fabric, which when rubbed heavily upon the surface to be cleaned, will serve to carry away the loose flakes, which could possibly cause self-ignition, without exposing the polished surfaces of the head and piston. A carbon deposit upon the cylinder head rarely takes the form of scales because of its perfect cooling.

"My observation leads me to believe that the tendency to carbonize is growing with the lowering in the grade of the petrol supplied for fuel purposes. In short, it is my experience, sup-

ported by the judgment of many others with whom I am associated, that the principal source of carbon deposit is the imperfect combustion experienced regularly upon the road with all carbureters and engines. It is doubtless true that road dust and lubricating oil have a considerable influence in the accumulation of carbon upon the surfaces of the explosion chamber and head of the piston and valves in an indirect manner, but the carbon itself, I am convinced, comes largely from imperfectly consumed fuel. The lubricating oil furnishes the moist element which collects and holds this gasoline carbon from the time of the occasional periods of imperfect combustion until it is thoroughly burned on by later higher temperatures under full throttle.

"Attention is properly called to the fact that the sleeve valve engine, while it shows as great thickness of carbon deposit as the poppet valve, does not suffer from its presence, and makers of the latter are admonished to study the cause of the poppet valve's serious defect. It is also asserted that the two-stroke engine, as well as the sleeve valve, is free from the damaging effects of the carbon deposit, but no explanation of this condition is vouchsafed.

"That the conclusions of these authorities are well based is evident from the fact that every owner of a sleeve valve motor will testify that the power and sweet running of his engine *increases* with use, which fact has caused a great deal of speculation.

"A limited carbon deposit accomplishes two things: First, it increases to a limited extent the compression by reducing the compression space. Second, the coat of carbon acts as an insulator and prevents the transmission of heat from the piston top and cylinder head, which heat, instead of wasting through these walls into the cooling water or base chamber, is put to useful work. In the limited extent of this accumulation lies the secret of the non-knocking of the sleeve valve motor."

Timing 8 Cylinder V Motors.—Several cars of 1915 design will be found to incorporate 8 cylinder V motors of the general form shown at Fig. 159. These have two blocks of four cylinders each mounted on a common crankcase and disposed as shown in order to reduce the length of the engine. While the power plant shown is a French design, the American engines of the same type follow the

construction indicated very closely. The best arrangement of the cylinders is with the center lines disposed at an angle of 45 degrees from the vertical center line of the motor. This indicates that the cylinder center lines are separated by an angle of 90 de-

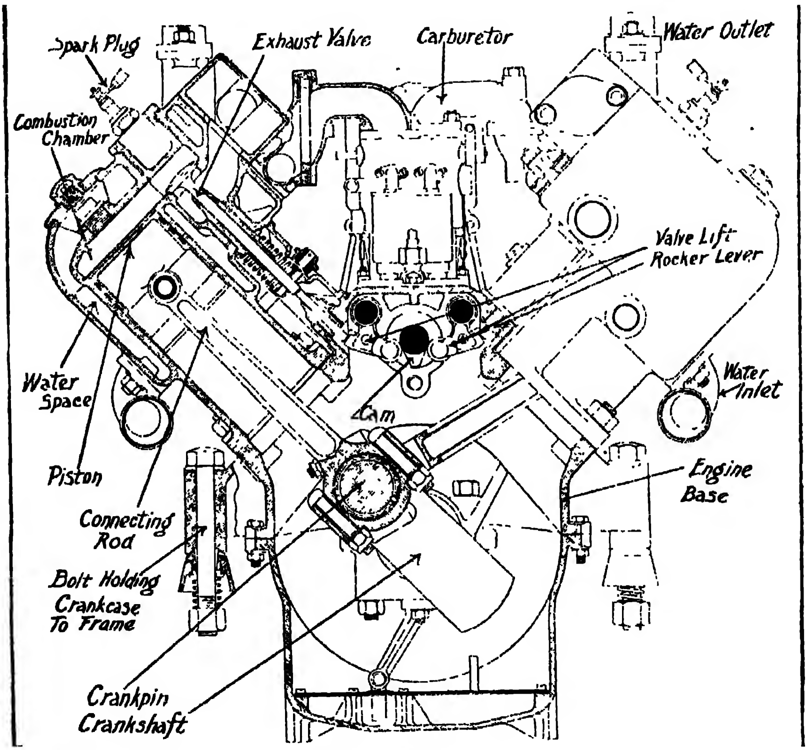


Fig. 158.—Eight Cylinder V Engine of DeDion Design.

grees. This arrangement makes it possible to operate 16 valves with eight cams. The method of valve operation is clearly outlined at Fig. 160, the view at A being enlarged to show the disposition of the valve plunger lifters or cam riders in relation to the camshaft. The valve stem clearance may be regulated as desired by the conventional pattern of adjusting screws. The same instructions that apply to timing a four cylinder motor may be

followed in setting the valves of an eight cylinder form, the only precaution to be observed is that the cylinders will fire in the proper order.

Views at Fig. 163 show the relative movements of the piston for a quarter revolution of the crankshaft. At A, the crankshaft position is such that the cylinders on one side are starting to function just as would be the case in a four cylinder motor with the

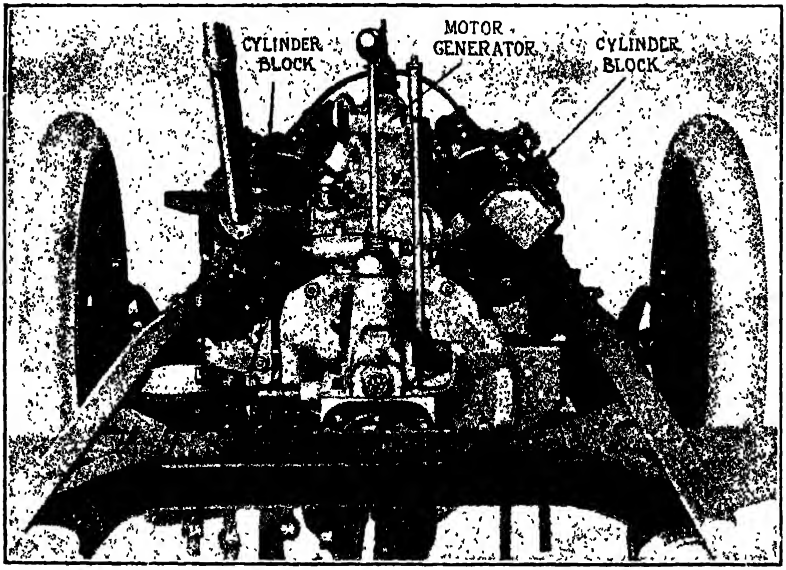


Fig. 159.—Rear View of Cadillac Eight Cylinder V Engine Installed in Frame.

crankshaft vertical, i. e., two pistons are at the bottom of the stroke and two pistons are at the top. Rotating the crankshaft 45 degrees or ⅛ of a revolution produces the condition outlined at D. In this none of the pistons are at the top of the stroke. Rotating the crankshaft another 45 degrees gives us the conditions shown at C, which is the opposite to that outlined at A. The order of firing in the Cadillac motor which is one of the most popular is as follows: No. 1 cylinder on the left fires first; then No. 4 cylinder on the right; No. 3 left and No. 2 right; then No. 6 on the

right, No. 7 on the left; then No. 8 on the right, and lastly No. 5 on the left. It is possible to have the valves in an eight cylinder

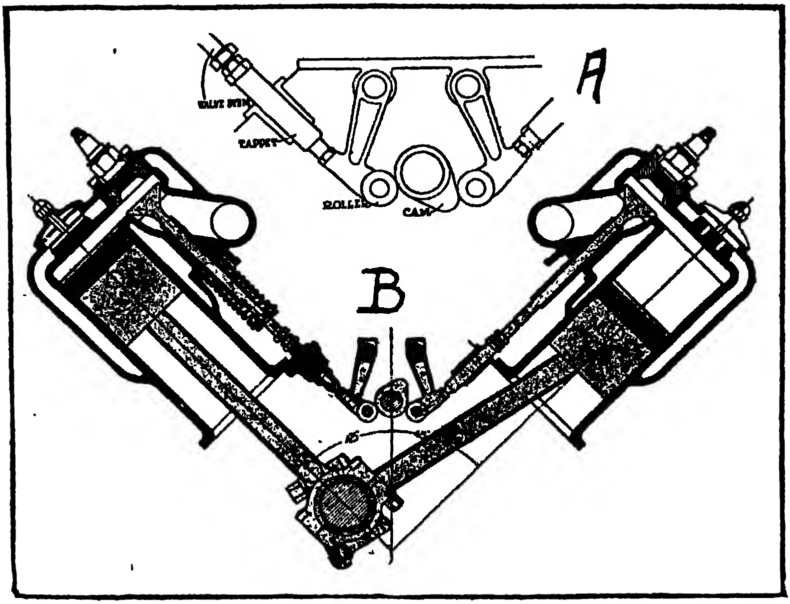


Fig. 160.—How Valves of Cadillac, Eight Cylinder V Engine, are Operated.

motor open in quite a variety of ways as consideration of the following possible firing orders will indicate:

POSSIBLE FIRING ORDERS—8-CYL. V TYPE, 90°

1 R—	1 L—	2 R—	2 L—	4 R—	4 L—	3 R—	3 L
1 R—	1 L—	3 R—	2 L—	4 R—	4 L—	2 R—	3 L
1 R—	1 L—	2 R—	3 L—	4 R—	4 L—	3 R—	2 L
1 R—	1 L—	3 R—	3 L—	4 R—	4 L—	2 R—	2 L
1 R—	4 L—	2 R—	3 L—	4 R—	1 L—	3 R—	2 L
1 R—	4 L—	3 R—	3 L—	4 R—	1 L—	2 R—	2 L
1 R—	4 L—	3 R—	2 L—	4 R—	1 L—	2 R—	3 L

R indicates right-hand block. L indicates left-hand block. Cylinders numbered from front to rear—1, 2, 3, 4.

When one cam serves two opposite valves, there is only one practical timing, the inlet must open on top center and close 45 degrees after bottom center; the exhaust valves must open 45 degrees in advance of bottom center and close at top center. In the King eight cylinder motor, if we call the first cylinder on the right No. 1, the second on the right No. 2, and so on and the first on the left No. 5, the next on the left No. 6 and so on, the firing order will be 1, 8, 3, 6, 4, 5, 2, 7, or using the other method where each cylinder block is numbered from No. 1 to 4 we have a firing order as follows: 1R—4L—3R—2L—4R—1L—2R—3L, the last in preceding table.

How Silent Chains Are Adjusted.—The tendency to employ chains for driving the shafts for valve control and for the magneto as well as for the gearbox, which originated in England is finding some favor in France and America. The technical opinion of many experts leans strongly to the idea that all the advantages of silent chains can be attained by using miter or herringbone or even straight spur gears, if only close attention is paid to the correct shaping of the gear tooth curves in each case. As a matter of complying with the inscrutable dictates of automobile fashion, some activity is displayed, however, among automobile manufacturers to get the benefit of the experience with the chains which has been gained in England. In this respect the precautions which must be taken to obviate the effects of that lengthening by wear to which all chains are subject, come in the first line. They also constitute the most important objection to the adoption of chains. First, a considerable initial stretch must be affected in each chain, unless this is done in advance and at some additional cost by the chain maker, by running it under load for a short time on a special machine established for that purpose, and subsequently the normal wear of the chain pins and bushings, after the chain has been placed in commission in a car, determines a further lengthening, much smaller in percentage than the initial stretch but yet large enough that it cannot be neglected.

If a chain is used that is larger than is needed, as on the Cadillac eight cylinder V type engine shown at Fig. 161, it is not necessary to provide adjusting means because the chain will not

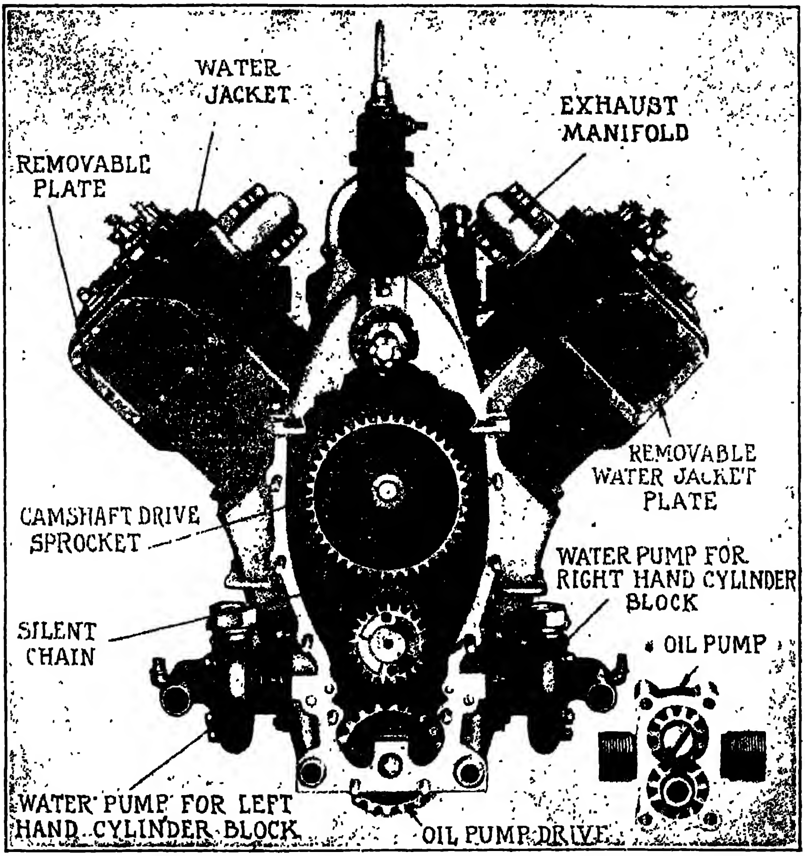


Fig. 161.—Method of Driving Camshaft of Cadillac Eight Cylinder Motor by Silent Chains.

lengthen if it is not stressed unduly, the strain being very much reduced by using a wide chain having a margin of safety greater than usually allowed in components of this kind. Where the chain is apt to lengthen due to wear in the link plates and rivets, some provision must be made for adjustment. The practice of some European designers may be considered of value in this connection.

These methods are illustrated in Fig. 162. Armstrong, Whit-

worth & Co. (A), provide an eccentric sleeve adjustment for the magneto shaft giving a maximum of 6 millimeters lateral displacement. Gregoire (B), uses two eccentric sleeves, so that up or down movement of the pinion can be avoided, probably with a view to leaving the valve timing entirely unaffected.

Chenard-Walcker (C), pushes the whole sprocket pinion bearing as well as the baseplate of the magneto outwardly in a recti-

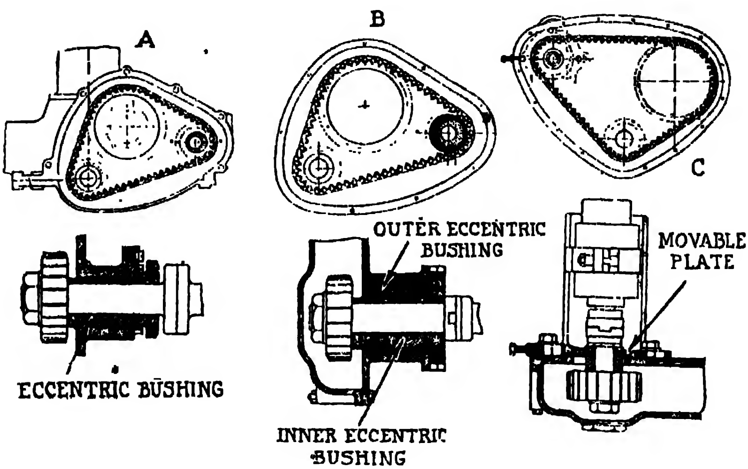


Fig. 162.—How Silent Chains may be Adjusted for Wear.

linear movement by means of a drawbolt, locking the adjustment with setscrews.

The method used on the King engines of this form is clearly shown in accompanying front view of the motor with timing gear case cover removed. A pinion mounted on a slotted plate which is adjustable can be moved to take out any slack in the chain as desired.

Precautions in Reassembling Parts.—When all of the essential components of a power plant have been carefully looked over and cleaned and all defects eliminated, either by adjustment or replacement of worn portions, the motor should be reassembled, taking care to have the parts occupy just the same relative posi-

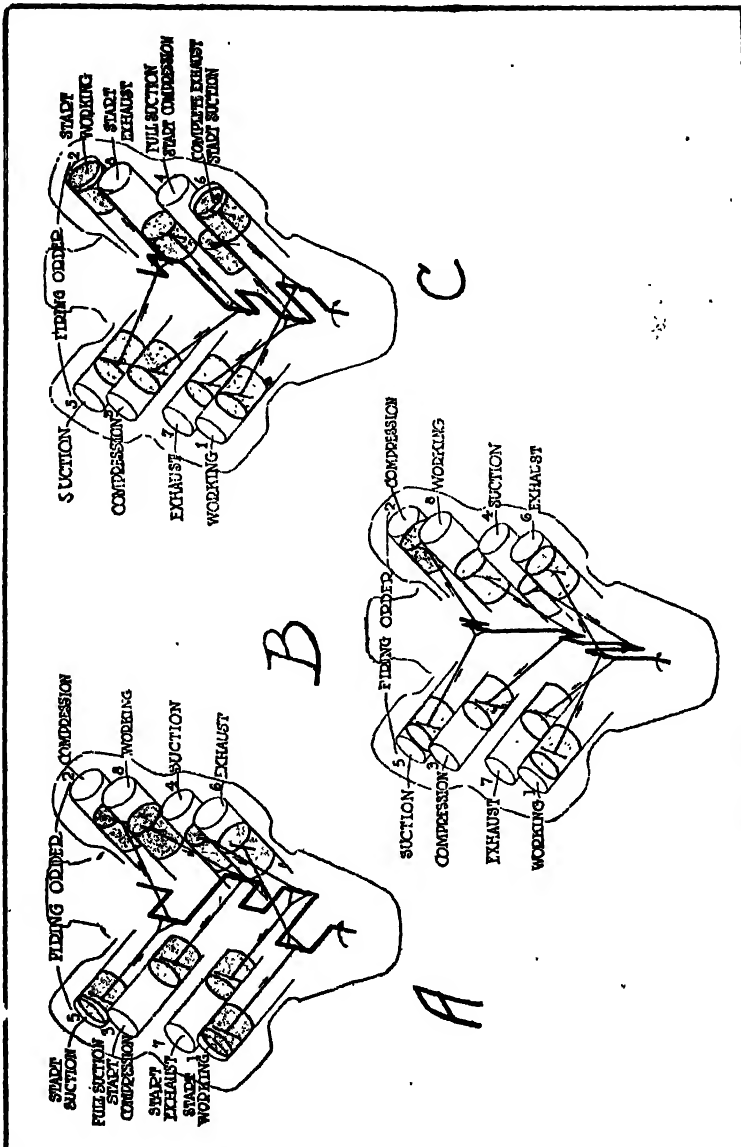


Fig. 163.—Diagrams Showing Movements of the Piston for Different Positions of the Crankshaft in Eight Cylinder V Motor.

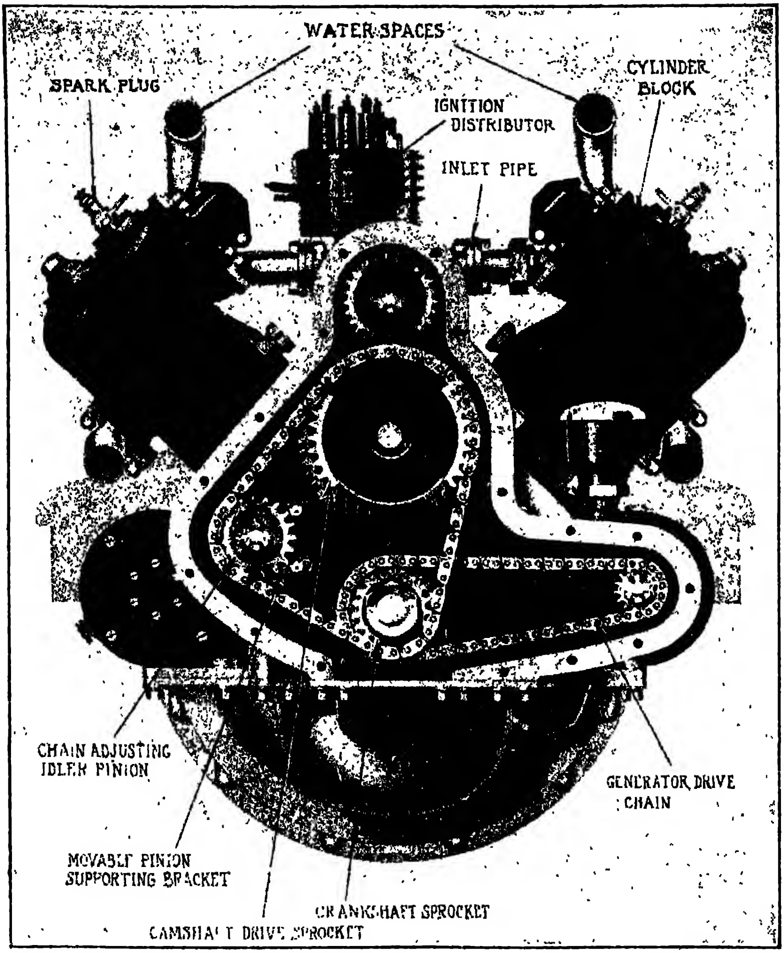


Fig. 164.—Front View of King Eight Cylinder Motor. Note Method of Camshaft Drive Chain Adjustment.

tions they did before the motor was dismantled. As each part is added to the assemblage care should be taken to insure adequate lubrication of all new points of bearing by squirting liberal quantities of cylinder oil upon them with a hand oil can or syringe

provided for the purpose. In adjusting the crankshaft bearings tighten them one at a time and revolve the shafts each time one of the bearing caps is set up to insure that the newly adjusted bearing does not have undue friction. All retaining keys and pins must be positively placed and it is good practice to cover such a part with lubricant before replacing it because it will not

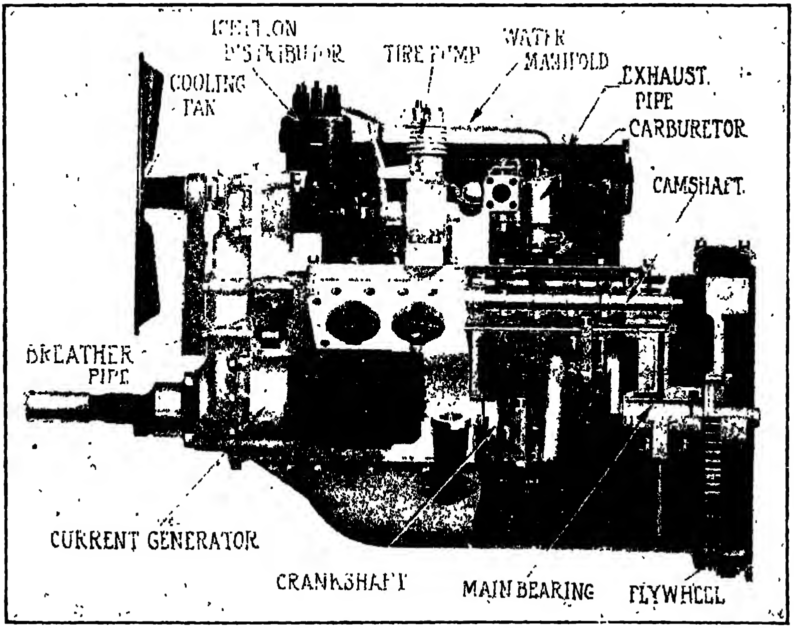


Fig. 165.—Longitudinal Part Sectional View of King Eight Cylinder Motor, Showing Important Parts.

only drive in easier but the part may be removed more easily if necessary at some future time. If not oiled, rust collects around it.

When a piece is held by more than one bolt or screw, especially if it is a casting of brittle material such as cast iron, the fastening bolts should be tightened uniformly. If one bolt is tightened more than the rest it is liable to spring the casting enough to break it. Spring washers, check nuts, split pins or other locking means should always be provided, especially on parts which are in motion

or subjected to a load. Before the cylinders are replaced on the engine base, heavy brown paper gaskets should be made to place between the cylinder base flange and top portion of the engine crank case. The best method of making these gaskets is to tamp them out by placing the sheet of brown paper over the mouth of the cylinder and directing a series of light blows with a machinists' ball peen hammer against the sharp edges of the casting. This will cut the paper exactly to the form of the base flange and cylinder bore The holes in the flange may be indicated in the same manner or may be punched through with a steel drift. The same process may be used in making irregular shape gaskets of other materials such as asbestos or rubber packing.

Before placing the cylinder over the piston it is imperative that the slots in the piston rings are spaced equidistant and that the piston is copiously oiled before the cylinder is slipped over it. When reassembling the inlet and exhaust manifolds it is well to use only perfect packings or gaskets and to avoid the use of those that seem to have hardened up or flattened out too much in service. If it is necessary to use new gaskets it is imperative to employ these at all joints on a manifold because if old and new gaskets are used together the new ones are apt to keep the manifold from bedding properly upon the used ones. It is well to coat the threads of all bolts and screws subjected to heat, such as cylinder head and exhaust manifold retaining bolts with a mixture of graphite and oil. Those that enter the water jacket should be covered with white or red lead or pipe thread compound. Gaskets will hold better if coated with shellac before the manifold or other parts are placed over them. The shellac fills any irregularities in the joint and assists materially in preventing leakage after the joint is made up and the coating has a chance to set.

In replacing cylinder head packings on cars like the Ford, it is well to run the engine for a short while, several minutes at the most, without any water in the jacket in order to heat the head up thoroughly. It will usually be found possible to tighten down a little more on all of the cylinder head retaining bolts after this is done because if the gasket has been coated with shellac the surplus material will have burnt off and the entire packing bedded

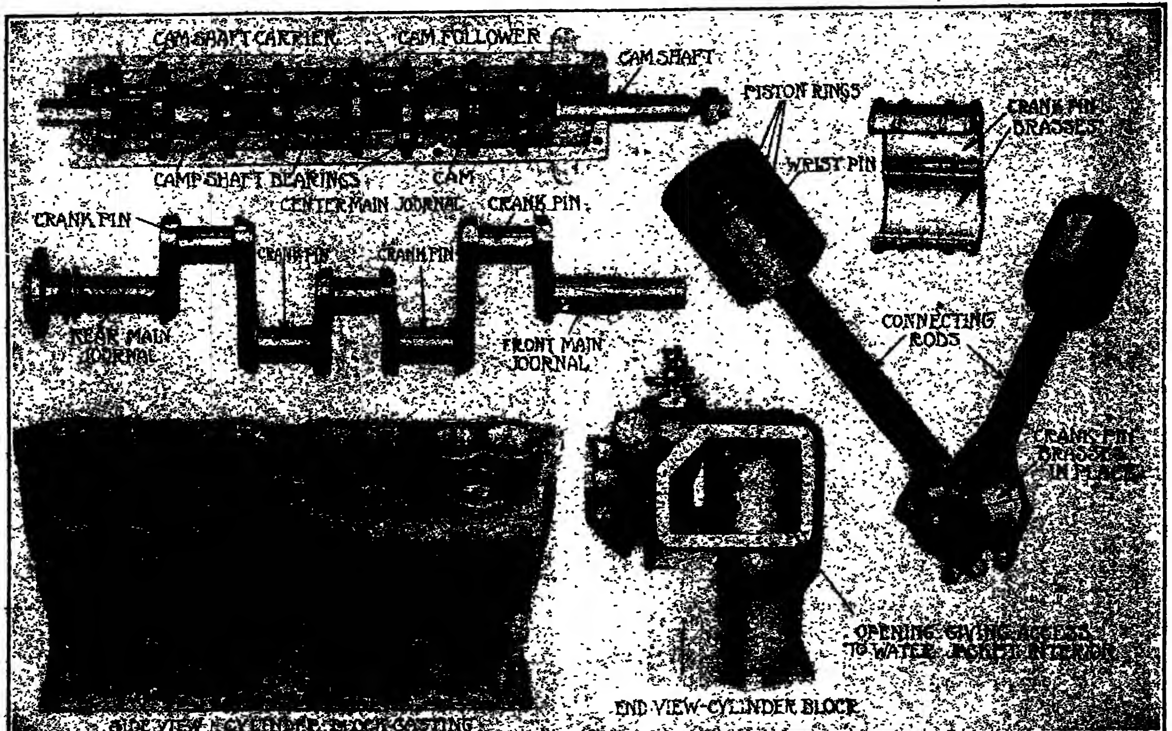


Fig. 166.—Group of Parts of Cadillac Eight Cylinder V Motor, Showing Construction of Important Members of Assembly.

down. Care should be taken when using shellac, white or red lead, etc., not to supply so much that the surplus will run into the cylinder, water jacket or gas passages.

Loose Flywheel.—Many mysterious knocks, which are often attributed to worn bearings are due to the flywheel being loose on the shaft. In a number of the earlier forms of cars and in nearly all marine engines the flywheels are held to the shaft by a simple gib key. It often happens that these keys become worn and the wheel is slightly loose on its supporting shaft. When the engine is revolving at high speed a pronounced thump or knock will be produced because of the hammering action of the flywheel upon the loose key. The proper remedy for such a condition is to make a new key that will fit the keyways in flywheel and shaft and drive it tightly in place. In some constructions the flywheel is installed on a taper on the crankshaft and in addition to the key it is held in place by clamp nuts. These nuts sometimes become loose and permit the flywheel to back off the taper enough to produce noise. In practically all modern forms of motor the flywheel is secured to a flange forged integrally with the crankshaft by means of bolts. It may be possible for the bolts to loosen which will permit the flywheel to rock and to pound the holes out oval. This condition is easily remedied by reaming or drilling the worn holes to the next largest standard size and to fit larger bolts to correspond.

Two Cycle Motors.—This form of power plant has received but limited application in automobiles, but the repairman may have occasion to investigate irregular action of some old model car using this type of motor or may be called upon to repair a marine engine of this type. It will be evident that a worn cylinder, piston rings or piston will result in the loss of compression as in any motor and that loose connecting rods or main bearings will produce noisy operation just as in the four-cycle type. In the two-cycle motors there are other conditions to be looked for besides those involving normal depreciation of the mechanism. There are two chambers to keep tight instead of one as in the four-cycle type. In the two-cycle form it is not hard to maintain compression in the combustion chamber because there are no valves to leak and the only chance

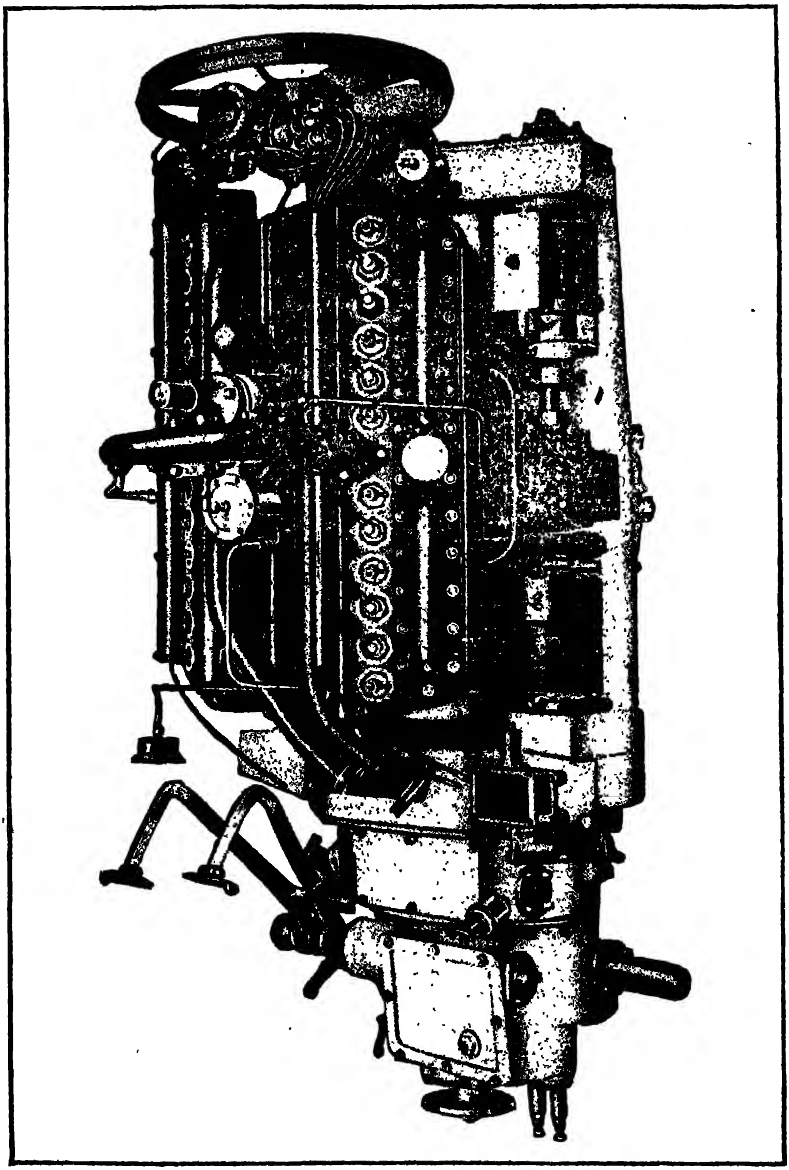


Fig. 167.—Packard "Twin Six" Motor. Latest Power Plant Development.

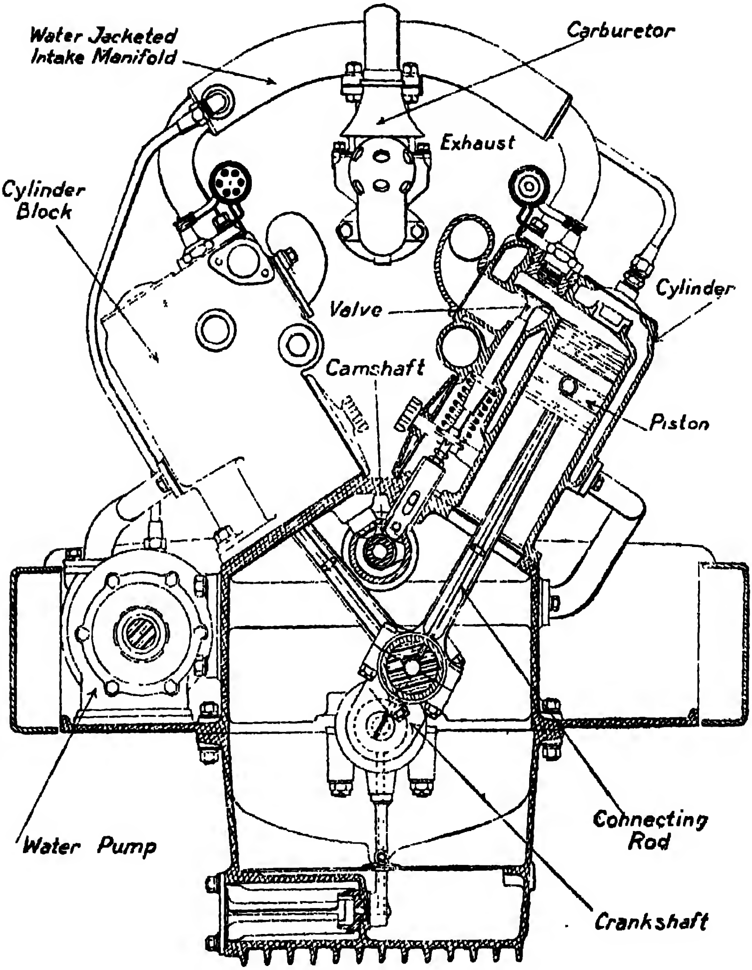


Fig. 168.—End Sectional View of Packard "Twin Six" Motor, Showing Arrangement of Cylinders.

for escape is by worn piston rings. It is imperative, however, that a certain amount of compression be maintained in the crank case of most two-cycle engines because the degree of compression in the crank case determines the rapidity of transfer of explosive gas from the base where it is first received to the combustion chamber where it is exploded. Because of this the main bearings demand more attention than do those of a four-cycle engine because they must be fitted so well that there is no possibility of leakage through them. Similarly the packings between the cylinder and engine base and between the crank case halves must be carefully maintained. In examining the piston and cylinder care must be taken to remove any deposit of carbon from the baffle plate or deflector which is usually cast integral with the piston top, as any sharp point or corner would remain incandescent and would cause either base firing or premature ignition. Base firing is generally prevented by making the charge from the crank case pass through wire gauze in the by-pass passage. This prevents the flame igniting the explosive gas in the engine base because practically all of the heat is abstracted from any heated gas as it passes through the mesh of the screen. These screens sometimes become clogged with oil and reduce the speed of gas flow and consequently diminish the power output of the motor, the remedy is a simple one as it involves only the removal of the clogged screens and cleansing them thoroughly in gasoline before replacing.

The 12 Cylinder V Motor.—The last word in automobile motor construction is the "Twin Six" motor shown at Figs. 167 and 168. This is very much the same in construction as the eight cylinder forms, one marked difference being in the angle between the cylinders which is 60 degrees and in the use of crankpins wide enough so connecting rod big ends of two opposite cylinders may be placed side by side. Except for the multiplicity of parts which involves slight structural changes, the same instructions given for the repair of the simpler four cylinder engines apply to similar components of the eight and twelve cylinder power plants.

CHAPTER IV

COOLING, CARBURETION AND LUBRICATION SYSTEM FAULTS

Overheating—Systematic Location of Troubles—Deposits in Radiator and Piping—Cleaning Sand from Water Jacket—Deterioration of Rubber Hose—Pump Forms and Troubles—Methods of Fan Adjustment—Lacing Flat Fan Belts—Utility of Hose Clamps—Restoring Broken Water Pipe—Radiator Repairs—Defects in Carburetion Group—Gravity Feed System—Stewart Vacuum Feed—Air Pressure Fuel Feed—Air Pump Construction—Auxiliary Tanks—Exhaust Gas Pressure—Faults in Carburetor Float Chamber—Troubles in Mixing Chamber—How to Test Float Level—Effect of Air Leaks—Typical Carburetor Adjustment—Kingston—Schebler—Browne—Overland Schebler—Breeze—Stromberg Holley—Krice—Zenith—Rayfield—Speed Governors—Carburetor Installation—Soldering Metal Floats—Emergency Manifold Repair—Simple Oiling Systems—Typical Engine Oiling Method—The Constant Level Splash System—Forms of Oil Pumps—Where to Look for Trouble in Lubrication Systems—Cleaning Sight Feed Glass—Curing Smoking Motor—Practical Oil Filter—Requirements of Lubricating Oils.

The automobile power plant includes various auxiliary systems which are essential to motor action, and defects in these groups will materially influence the power output and regularity of running of the engine. Those that are usually grouped together are the cooling, carburetion and lubrication systems, because defects in any one of these may produce exactly the same effect on power plant operation. For instance, if the cooling system is not functioning properly this condition will be evidenced by overheating. The engine will run hotter than it should if lubrication is not adequate owing to friction which produces heating just as lack of proper cooling facilities will. If the carburetor supplies too rich mixture the engine will show this condition by running hotter than it should normally.

Systematic Location of Troubles.—When a motor overheats it is not possible to discover immediately whether the trouble is due

to improper mixture proportions, lack of adequate cooling or some defective conditions in the lubrication systems. If the motor is overheating because the mixture is too rich this can be determined by studying the character of the exhaust gases. If these have a pungent odor which not only assails the nostrils but which causes the eyes to water as well, and if black smoke is issuing from the muffler one may safely ascribe the overheating to a surplus of fuel in the mixture. Overheating is often due to carbon deposits and if these are at fault they may be removed as indicated in the preceding chapter. The only way to find out if excessive amounts of carbon are present in the combustion chamber is to remove a spark plug or valve chamber cap, and judge the amount of carbon present by inspection of the cylinder head interior. After one ascertains that the overheating is not due to poor mixture or to carbon deposits, it is necessary to inspect the various portions of the water cooling system and also the means of lubrication employed. If an engine is overheating because of lack of oil, it will pound much more than if the abnormal rise in temperature is due to failure of the water to circulate properly, or to the mixture being rich. Steam issuing from the radiator is considered a symptom of defective cooling and is stated to be an infallible indication by some authorities. The writer does not agree with this view, as any motor which is cooled properly when operating under normal conditions will often cause the water in the radiator to boil if the mixture is rich or if lubrication is poor. This does not necessarily indicate defects in the cooling system, but merely shows that the radiation is not energetic enough to absorb excessive or abnormal rise in temperature, due to some cause other than a defect in cooling.

The easiest thing to look for when one's sense of smell indicates that the trouble is not too rich a mixture is some defective condition in the water cooling system. There are two common methods of cooling in general use as outlined at Fig. 169. That shown at A is the simplest, because the water circulates by a natural principle that heated water will rise because it is lighter than cool water. The system shown is used on Overland cars and is the simplest possible method of cooling when liquids are employed for that

purpose. The heated water rising from the cylinders AAAA passes through the cast manifold B, to the top of the radiator D. After it flows through the radiator and becomes cool it returns to the cylinder jacket through the water manifold attached to the bottom of the jacket. The flow of water is indicated by the heavy black arrows, while the draught of cooling air passing through the

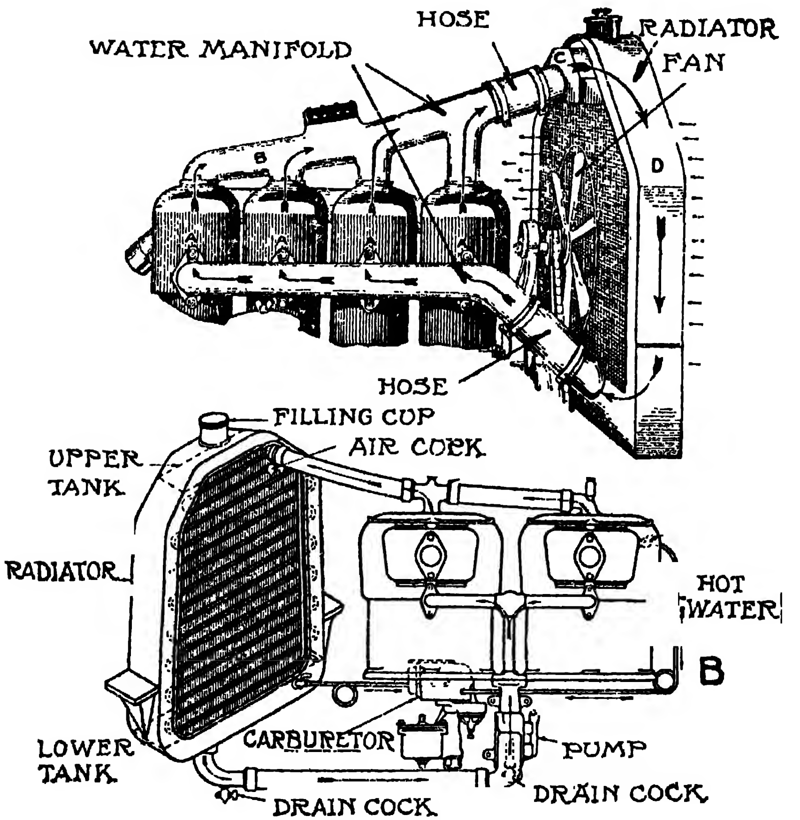


Fig. 169.—Methods of Cooling Automobile Engines Outlined. A.—The Overland Thermo-Syphon System. B.—Water Circulation by Water Pump.

radiator is shown by lighter arrows. In order to assure passage of air currents through the radiator when the car is standing still with the engine running, a power-driven suction fan is placed behind the radiator to draw the air through the interstices between the radiator tubes. With a simple thermo-syphon system the only thing that will interfere with proper circulation of the water is sediment in the water jacket or manifold, defective rubber hose, interruption of fan drive, and constriction of radiator passages. In the system of cooling shown at Figs. 169, B, and 170, a pump is depended on to promote circulation of the water, and in addition to the defects previously enumerated, poor circulation will result if the water pump or its driving means are at fault. The complete cooling system of the Packard four cylinder car is shown at Fig. 171, with all important parts clearly outlined. It will be noticed that whether the thermo-syphon or pump circulation system is used that a cooling fan driven from the engine is considered necessary.

Overland Model 82 Cooling System.—The cooling system (Fig. 170) of the Overland Model 82 is pump actuated. The pump is located on the left hand side of the motor and driven by the magneto shaft, pumping the water from the lower part of the radiator through and around the water areas of all cylinders, as shown in illustration, into the top of the radiator. It is cooled in its downward passage through the radiator and recirculated by the pump. The rapidity of circulation of water is governed by the speed of the motor. The cooling system is therefore positive and absolutely reliable in its action.

The water pump (Fig. 174) is lubricated by means of a compression grease cup. The pump shaft is drilled in the center so that the grease from the one cup supplies both pump bearings. This cup should be given a turn or two every four or five hundred miles. The pump is provided with a drain cock, which should be opened about once a week to let all water and accumulated dirt run out. This drain cock may be used in conjunction with the drain cock on the water pump inlet elbow to drain the water from the cylinders when the car is to be stored in cold weather. The water pump is packed with asbestos and heavily graphited. The glands are countersunk, making the packing conical in shape.

thus preventing leakage of water without undue pressure on the pump shaft.

After a new car has been run a thousand miles the stuffing box nut on each side of the pump should be tightened a trifle. Cooling of the water through the radiator is aided by means of a four-blade fan set on the front end of the motor and driven by means of a "V" belt from the pump shaft. If the leather belt on the

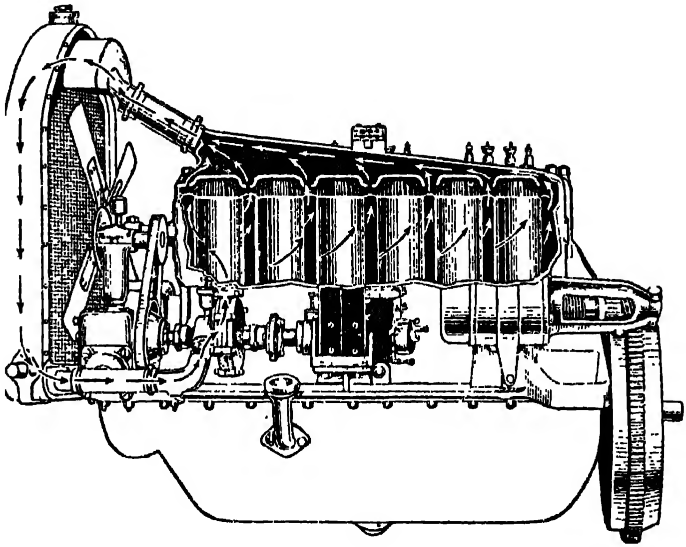


Fig. 170.—Overland Six Cylinder Engine Showing Cooling System Parts.

fan stretches from considerable use, it may be tightened by loosening the stud on the fan bracket and raising the fan enough to remove the slack from the belt.

Deposits in Radiator and Piping.—The form of radiator most generally used at the present time has a number of very narrow tortuous passages through which the water must pass in going from the upper compartment where it is discharged after leaving the motor cylinders, to the lower compartment where it collects after being cooled and from which it is drawn by the circulating

pump. The water used in some localities for cooling contains much matter either in suspension or solution which will form scale or a powdery deposit in the radiator tubes. It does not take much scale to seriously reduce the ratio of heat conduction between the heated water inside of the tube and the cooling air currents which

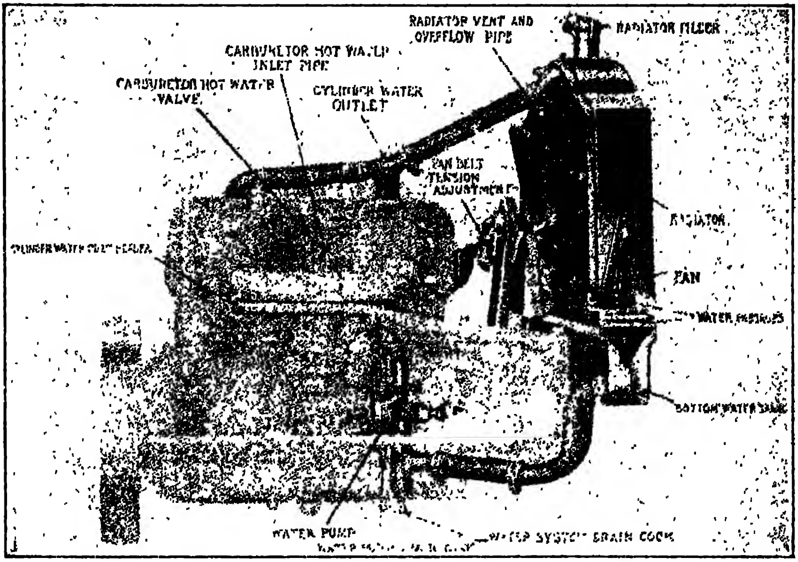


Fig. 171.—The Packard Cooling System, Showing All Important Components.

are circulated about their exterior. As cylinders are generally of cast iron, a certain amount of rust will be present in the water jacket, and this also may get into the radiator piping. If an anti-freezing solution using some salt as a basis such as calcium-chloride is employed, after this has been circulated through the radiator and piping for a time it may deposit solid matter in the form of crystals in the piping or radiator. Anti-freezing solutions that include glycerine may have a chemical action due to the acid sometimes found in the cheap commercial grades of glycerine employed for this purpose. This chemical action results in the deterioration of the water jacket walls, and also contributes to the rust deposit.

Cleaning Sand from Water Jackets.—In some cases excessive heating of an engine has been found to be due to a retention of part of the sand core in the water jacket of the cylinder casting. This is very apt to be the case if the casting is in such form that the water jacket interior is inaccessible. On those types of unit castings where a large side plate is employed to close an opening that occupies practically the entire side of a water jacket, no difficulty obtains in cleaning out all core sand, but where this precaution is not taken and the core supported by prints of small size, there is considerable difficulty in clearing the casting in some cases. For those not familiar with foundry practice the writer may say that the core is that portion which is used in the mold to represent the space between the cylinder wall and water jacket, as it is necessary to use some such filler in the mold when pouring the molten metal into the impression left by the pattern to form the cylinder. Cores are usually made of fine sand held together by binding material, and in some cases with pieces of wire running through as a re-enforcement, the whole being baked to form one piece before it is placed in the mold. A piece of this core may become lodged in some angle or corner and remain there even though the greater portion of the core is removed by the foundryman. This may not become loose until the engine has been in use for some time, and then it may be carried into a pipe or opening and partially or wholly interrupt the water circulation. The piece of core may dissolve and deposit considerable sand in the water jacket which will collect in some corner where it may affect circulation. In order to remove all traces of sand, where mechanical means are not practical, an authority recommends a solution of hydrofluoric acid and water, the proportions being about one part acid to ten of water. This should be poured into the jacket and allowed to stand over night, which will loosen the sand or dissolve it. The cylinder jacket should be thoroughly drained and all traces of the acid removed by flushing thoroughly with hot water under pressure. Hydrofluoric acid is the only one that will attack sand, and it is well to remember that it has the same effect on glass which is usually indifferent to the action of the other common acids. Care must be taken, therefore, to keep it in the

special rubber container, in which it is received from the chemical supply house. While this chemical will also attack the metal of which the cylinder is composed, the diluted solution recommended will have no material effect in the short time required to thoroughly dissolve the sand.

It is not advisable to use the diluted acid in the water spaces of the radiator, as the brass or copper used in this part of the cooling system is much thinner than the material employed in the water jacket, and is also more easily attacked by the acid. For cleaning out the water spaces of a radiator a solution of potash or washing soda may be used. This will cut the rust and some forms of scale and will dissolve them or loosen them sufficiently so the deposits may be thoroughly flushed out with water or steam under pressure. The solution will work more rapidly if it is brought to the boiling point before placing it in the radiator. The potash solution is also valuable in removing rust from the water jacket interior.

Incrustation is most commonly caused by carbonate of lime which is held in solution in some water as a bicarbonate; therefore, when the water is heated the carbonic acid is driven off and the carbonate is precipitated in the form of a muddy deposit which hardens in the presence of heat into a nonconducting scale in those portions of the water jacket where the heat is greatest, and which remains in the form of a powdery deposit in the radiator tubes where the heat is not great enough to harden the sediment. Sometimes the deposit is sulphate of lime, this also being found in the water available in some localities. The reason that water contains so many impurities is because it is one of the best known solvents. Pure water is never found in nature and can only be obtained by a process of distillation. The purest natural water is rain, and if this is collected before it touches the earth it contains only such impurities as may be derived from the atmosphere, these consisting of gases in the open country such as nitrogen and carbon dioxide. That falling over towns absorbs quantities of acids and soluble salts. Rain water collected near the ocean contains chlorine. The source of water supply in many communities is some river flowing through or within a short distance. A large variety

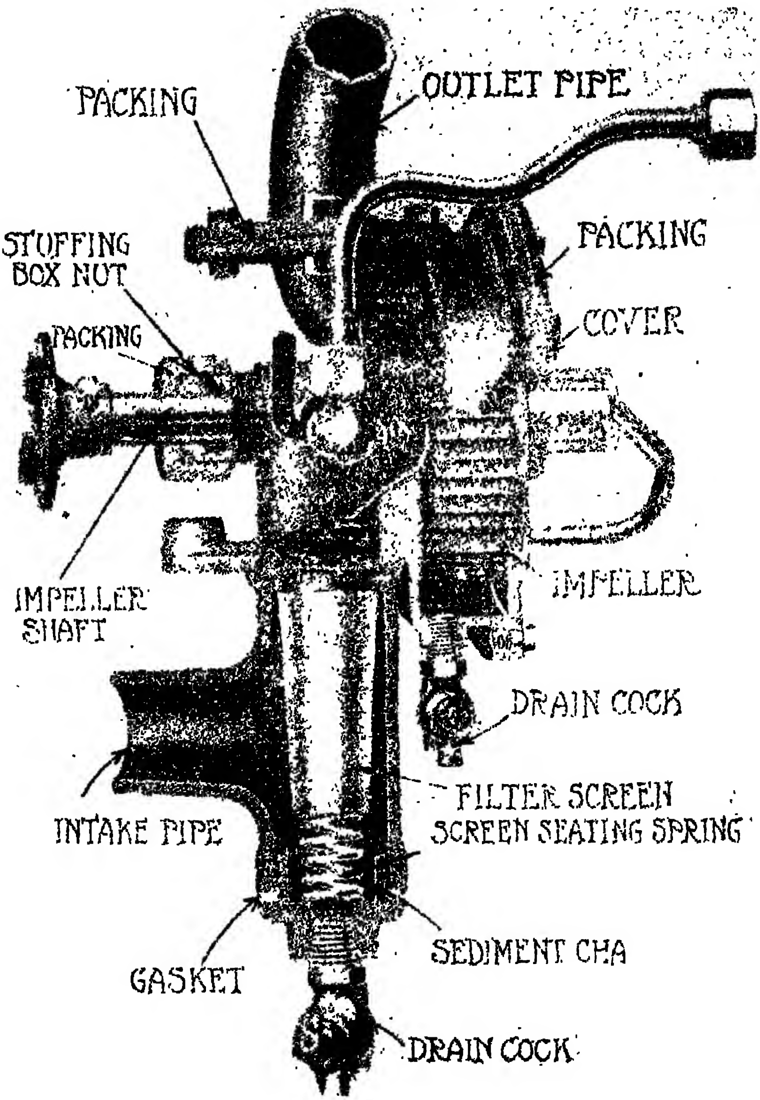


Fig. 172.—Part Sectional View of the Packard Centrifugal Water Pump.

of substances may be found in solution in river water, the main element being derived from the rocks through which the water of the springs which have fed the river has percolated. Then, again, river water is often contaminated by the drainage of towns or of manufacturing establishments situated on the banks of the river. Spring waters also contain many salts and minerals. Water that has been obtained from ponds is often rich in vegetable matter. As it is not practical for the motorist to use distilled water for filling the radiator and water jackets, it is apparent that the water obtained from the other sources will contain impurities in various amounts. If the water is very hard or contains much salt, it will be well for the motorist to save rain water for use in the cooling system. The best solvent to use depends entirely upon the composition of the water, and as this varies in all portions of the world it is not possible to enumerate the best chemicals for removing incrustation or to neutralize the material in solution. The advice of a local chemist should be sought in matters of this kind.

Deterioration of Rubber Hose.—In order to avoid fracture of the water manifolds from vibration, as would be the case if these were attached to the radiator by nonflexible metallic connections, it is customary to interpose pieces of rubber hose between the radiator and the manifolds as shown at Fig. 169, A, and where the manifolds are the built-up form, rubber hose often forms an important item of the piping system as shown at Fig. 171. While it is imperative to use the best quality steam hose for this purpose, even this material may depreciate in use. A certain amount of oil and grease will find its way into the cooling system, usually from the grease cups used to lubricate the water pump bearings. This causes the hose to rot inside as the oil has a chemical action upon the rubber. Strips of the interior lining may become detached and may interfere with water circulation by constricting the bore of the hose. If anti-freezing solutions containing glycerine are used, depreciation of the hose is inevitable. The best remedy is replacement of the defective hose with new, as this material is relatively inexpensive, in fact, one may obtain special hose connections for use on all the popular makes of cars from the large automobile

supply houses or manufacturers, these being cut the proper length and not needing any fitting.

Pump Forms and Troubles.—In the water cooling systems which employ a pump to insure positive circulation of the water one may experience cooling troubles if the pump becomes inoperative for any reason. Two forms of circulating pumps are commonly used. That shown at Fig. 172 is a centrifugal form in which the water is circulated by the rotation of a multi-bladed impeller in the casing, and the design outlined at Fig. 173 is a more positive form in which two gears are depended on to keep the water in movement. In the centrifugal form the water enters the pump casing at the center, and is thrown outward by the revolving impeller member, passing out of the case through an outlet pipe attached to the casing. In the gear pump the water enters the casing through either of two openings, and as it cannot pass directly from the inlet to the outlet on account of the tight fit of the gear teeth and of the gears in the casing, the only way it can flow from one side of the case to the other is by filling the tooth spaces of the gears and being carried around from the intake to the discharge opening.

Any condition that would interfere with rotation of the impeller of a centrifugal pump or the gears of a gear pump will interfere with circulation because the water cannot flow by natural means when the system is designed with a view of keeping it in motion by the use of a pump. It is possible for the pump driving means to fail, and in fact on many of the early model cars this was a very common trouble. At the present time water pumps are driven by positive connections with the camshaft, and there is but little opportunity for failure of the driving means. If a pump has been used for a long time the steel shaft on which the impeller is mounted may become rusted enough so that it will be weakened and will rupture. Sometimes the key or pin holding the impeller in place on the shaft will shear off, this being very apt to happen if the pump becomes filled with ice, a not uncommon occurrence in certain sections of this country during the winter season.

The continued rotation of the impeller of a centrifugal pump or the gears of the gear pump may cause wear in the pump casing.

If there is much space between the impeller and the pump casing the efficiency of the pump will be materially reduced. The only remedy for this condition is to replace the worn parts with new. In the centrifugal pump outlined at Fig. 172, which is an accu-

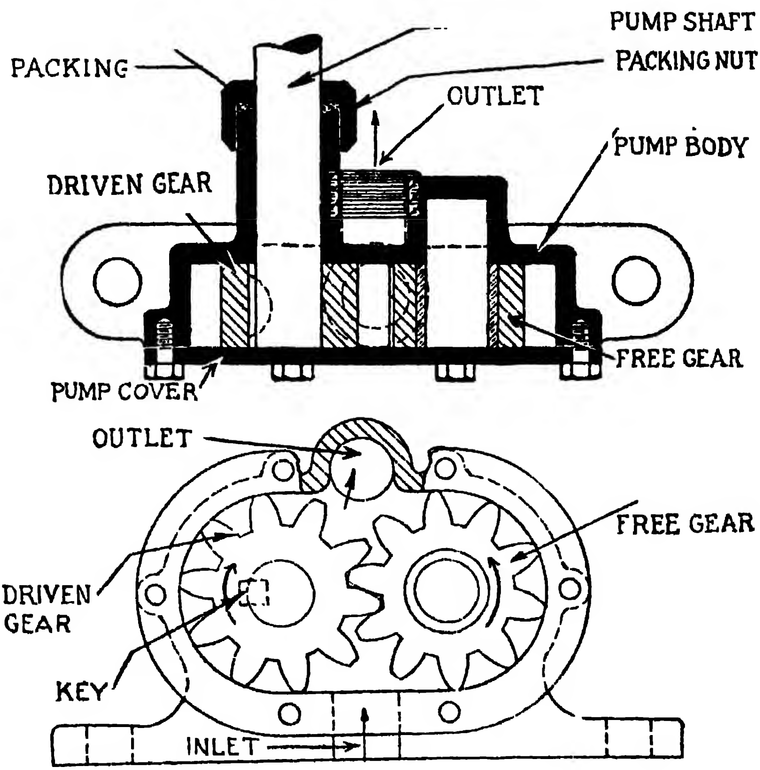


Fig. 173.—Sectional View Showing Construction of Gear Pump.

rate representation of the device used to circulate water on Packard four and six cylinder cars, it will be noticed that a filter screen is interposed between the intake pipe and the impeller chamber. The function of this screen is to remove all sediment from the cooling water with the object of preventing undue depreciation be-

tween the impeller member and the pump casing. In performing this function the screen may become clogged up, and will not permit the water to flow through it as promptly as it should. Provision is made for removing the strainer, and this should be taken out through the opening left after the sediment plug is removed and thoroughly cleaned before it is replaced.

One of the annoying conditions, though not a serious one, that is noticed in a water pump is leakage at various points. It is

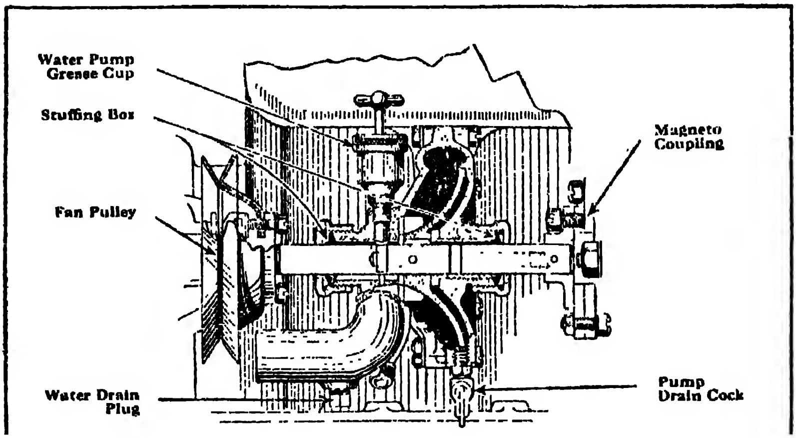


Fig. 174.—Sectional View Showing Overland Centrifugal Pump.

evident that there will be an opportunity for water to escape around the driving shaft if the stuffing box is not kept properly screwed up. The stuffing box is provided with a flexible hemp packing which may be compressed tightly against the shaft by screwing down the stuffing box nut and which forms an effective seal against escape of water. The stuffing box packing needs renewal from time to time in order that it may form an effective seal. Other points where a pump may leak are at the packings between the pump case or body and pump cover. If tightening the retaining screws or bolts does not stop the leaking, a new packing must be made to replace the defective one. Pump packings are usually of well shellacked cardboard cut to fit the pump casing

contour and with the screw holes punched through with a belt punch. Sometimes specially prepared rubber packings are used for this purpose.

If the pump is suspected of being defective the following points should be looked at in order: First, the driving means between the pump shaft and the engine; second, the retaining means for driving the impeller of a centrifugal pump or the driven gear of the gear pump; third, the fit between the gears or impeller and the pump casing interior; fourth, the fit between the impeller shaft and its bearings; fifth, the condition of the filter screen or strainer if a member of this nature is interposed between the pump intake and interior. The plunger form of pump, which is widely used in marine service because it is self-priming and must lift water, and the eccentric rotor forms, are seldom used on automobiles. Practically all pumps are either of the centrifugal pattern shown at Fig. 174 or of the gear pattern outlined at Fig. 173.

Methods of Fan Belt Adjustment.—If the motor heats up when the engine is running and the car standing still, it is necessary to inspect the fan driving means to make sure that this is functioning properly and that the fan is turning all the time the engine is running. Most fans are flat belt driven, and are mounted on some form of bracket that will permit of maintaining the fan driving belt at the proper tension to insure positive rotation of the fan blades. Some of the most common adjusting means are outlined at Fig. 175. At A the fan is mounted on an extension from an eccentrically mounted piece which may be turned in the clamping support to increase the distance between fan pulley and driving pulley centers. In addition to the eccentric, provision is made for keeping the fan belt at the proper degree of tension by a coil spring attached to a lever fastened to the fan supporting crank at one end and to the supporting bracket at the other. A similar method is shown at B, as the fan shaft is carried at one end of a bell crank which fulcrums on a supporting member in such a way that the tension of the coil spring on the long arm of the bell crank keeps the fan belt tight. At C the fan supporting standard is of tubular form and may be raised or lowered in the socket at its lower end. When the proper degree of ad-

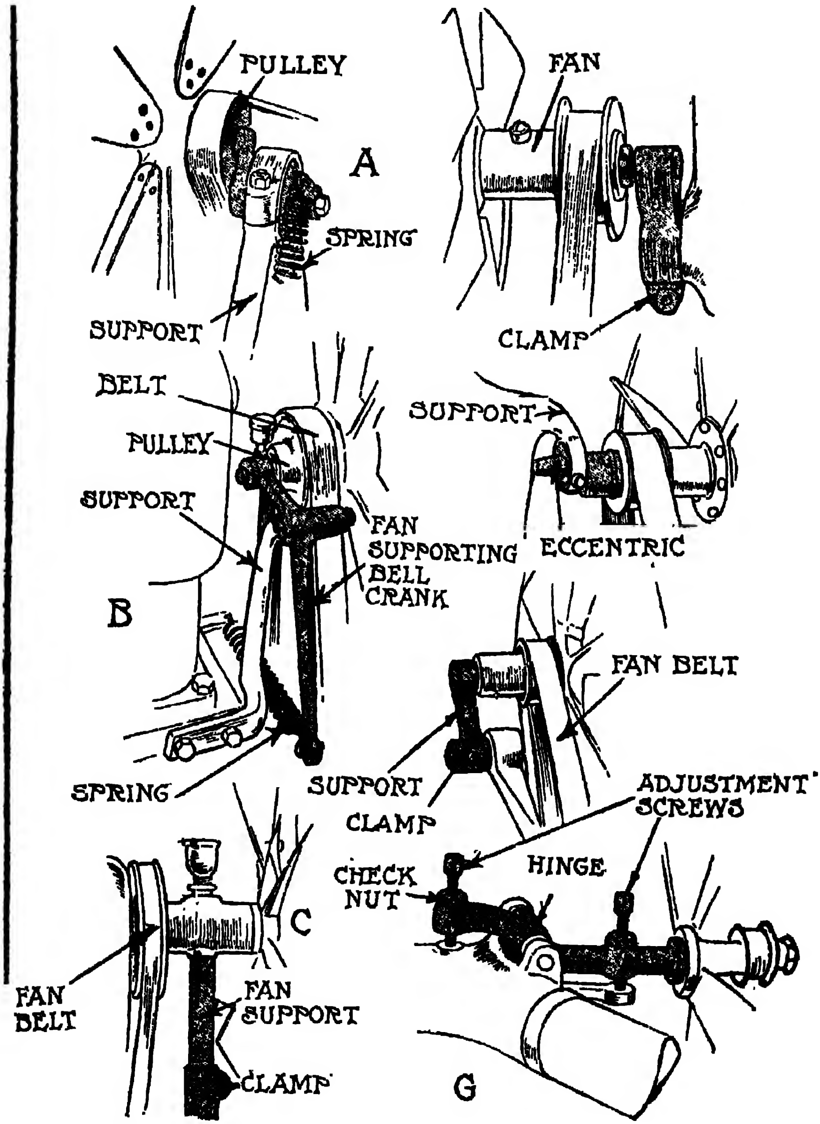


Fig. 175.—Methods of Adjusting Fan Belt Tension Outlined.

justment is secured the fan support may be firmly clamped in position. At D the fan is carried by a simple lever which swings about a boss attached to the cylinder. In order to alter the fan belt tension the clamp nuts may be loosened and the lever swung over until the belt is properly tightened. This adjustment is retained by tightening the clamp nut. Another application of the eccentric principle is shown at E, while another form of swinging supporting lever is outlined at F. The method at G is distinctive and very accurate adjustment of the belt tension may be secured. The fan hub rotates on one end of a lever which swings on a hinge formed integrally with the water manifold. Adjustment screws are provided at each side of the hinge to regulate the height of the fan. To tighten the fan belt the adjustment screw nearest the fan must be screwed down to raise the fan supporting lever, while that at the other end must be screwed out the same amount as the other is screwed in. When the proper degree of tension is obtained the adjustment screws may be locked with suitable check nuts.

Lacing Flat Fan Belts.—Lacing a fan belt is not a difficult operation, but unless care is taken in performing the work it is not easy to obtain a joint that will be neat and enduring. Certain preliminary precautions are necessary, an important point to observe being to make sure that the approximate edges of the belt be cut straight and at right angles to the longitudinal edges. The holes should be punched through with a belt punch, should be no larger than absolutely necessary, and should be distributed so as to weaken the belt the least. Belts used for driving cooling fans are seldom wide enough for more than three holes. It is not always possible to obtain rawhide belt lacing narrow enough to be used with these narrow belts, but it is possible to cut strips from the wider lacings such as can be obtained from any machine shop. The cutting may be done as indicated at A, Fig. 176, it being important that the knife have a very keen edge. The knife should be held between the fingers and the palm of the hand so the thumb can be employed as a guide to maintain the strip to be cut off of regular width. The lacing to be split should be given a preliminary cut of about two inches, then the knife should be placed with the

point resting on a bench, the blade being inclined slightly to secure a good cutting angle. Take hold of the strip to be cut off with the free hand, and by pressing the thumb firmly against the edge of the lacing and the bench draw the strip carefully upward. When the laces are cut, trim the ends to a long, narrow point, so these may be inserted in the holes punched in the belt.

In lacing a belt, first stick one lacing end through one of the center holes in the belt from the under side, which is the portion

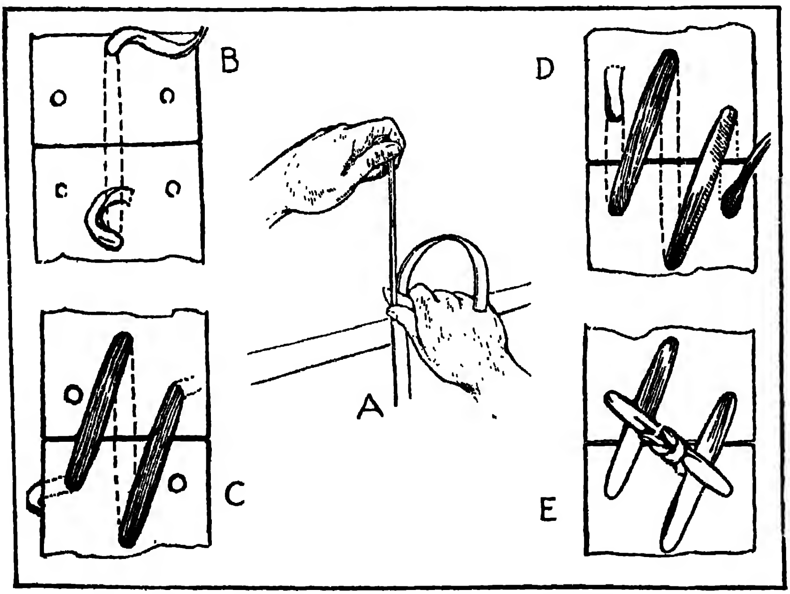


Fig. 176.—Method of Lacing Flat Fan Belt.

that will run next to the pulleys. Repeat with the other end of the belt lace and draw the ends of the belt together, as shown at B. Next place one end down through the side hole at the opposite end of the belt and bring it up through the hole on the same side of the end of the belt, as shown at C. Repeat this operation with the other end on the other side, as shown at D. The last step is to tie the ends of the lacing together at the top of the belt and cut off the surplus material. The three strips on

the under side of the belt will run parallel to each other and there will be no bunching to interfere with smooth running over the pulley. Metal belt lacings are sometimes used for this purpose, but these are not so satisfactory as the more pliable material, owing to the small diameter of the fan pulley. While the flat belt is the type most generally used, as it is the most serviceable, the round section belts are sometimes employed, these running

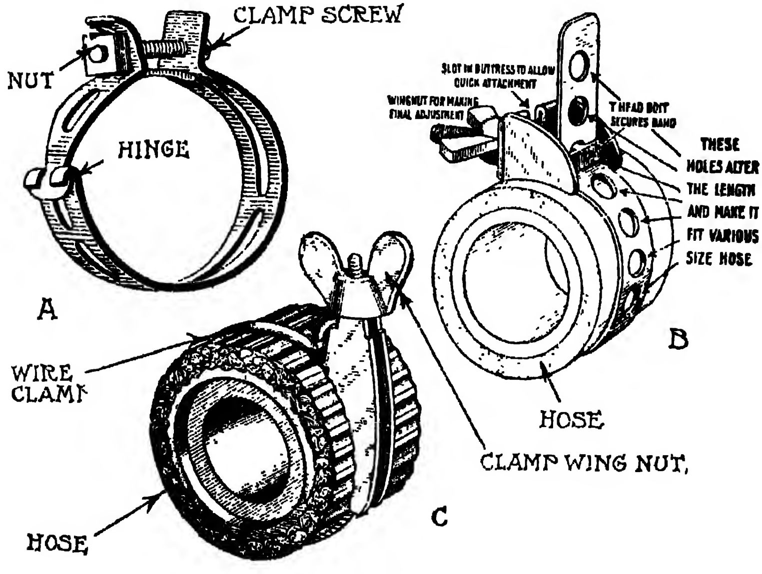


Fig. 177.—Hose Clamps of Good Design.

over grooved pulleys, or V belts running in 28 degrees straight side grooved driving members.

Hose Clamps.—The problem of compressing the rubber hose connections tightly enough around the manifold and piping of the radiator so they will not permit water to escape at the joint is difficult to solve unless hose clamps of good design are used to compress the hose in firm contact with the pipe. The simplest form of hose clamp to have received general application is shown at Fig. 177, A. This is made of a band of sheet metal, stamped

and bent to the form shown. A clamp screw is used to tighten the clamp around the hose. While this form is generally used, it is sometimes possible to screw these up so tightly that the open ends will abut without forming a tight joint. Difficulty is sometimes experienced with this form when replacing worn hose with new in closing the ends enough to catch the nut on the end of the clamp screw. This calls for the use of a longer clamp screw than that ordinarily furnished with the clamp. Another disadvantage of the form shown at A is that it will fit but one size of hose.

The Morgan hose clamp, which is shown at B, has the advantage of being quickly attached and of being used with several different sizes without alteration. As will be noted by the illustration, it includes a flat band and buttress, and a slot in the latter permits of quick adjustment. The band is secured by a T head bolt carrying a wing nut, as indicated. The band is provided with several holes for the purpose of fitting different sized hose. The clamps come in a variety of sizes and one of the good qualities of the design is that no tools are necessary to adjust it. Another form of clamp that has the advantage of being adaptable to a number of sizes of hose and which also insures a tight joint is shown at C. The main portion of the device is a stamped buttress which has a wire clamp fastened at one end, designed to encircle the hose forming a guide in the channel section for the threaded end of the clamping wire which is guided by it and which is tightened by means of a winged nut. These clamps are much superior to the cheap form of wire hose clamp used in connection with garden hose which calls for the use of a special tool to apply it. Adjustable clamps are necessary because it is imperative to have water joints of such a nature that they may be readily broken when necessary.

Restoring Broken Water Pipe.—In attempting to remove a water manifold made of brass tubing from a motor cylinder a workman used a large wrench in endeavoring to unscrew a nut rusted in place. The wrench slipped and bent the tubing in the manner indicated at Fig. 178, A. The tube was thin and was coupled to the cylinder by a flange and nut coupling, the pipe being flared at the end to seat against a corresponding male member screwed into

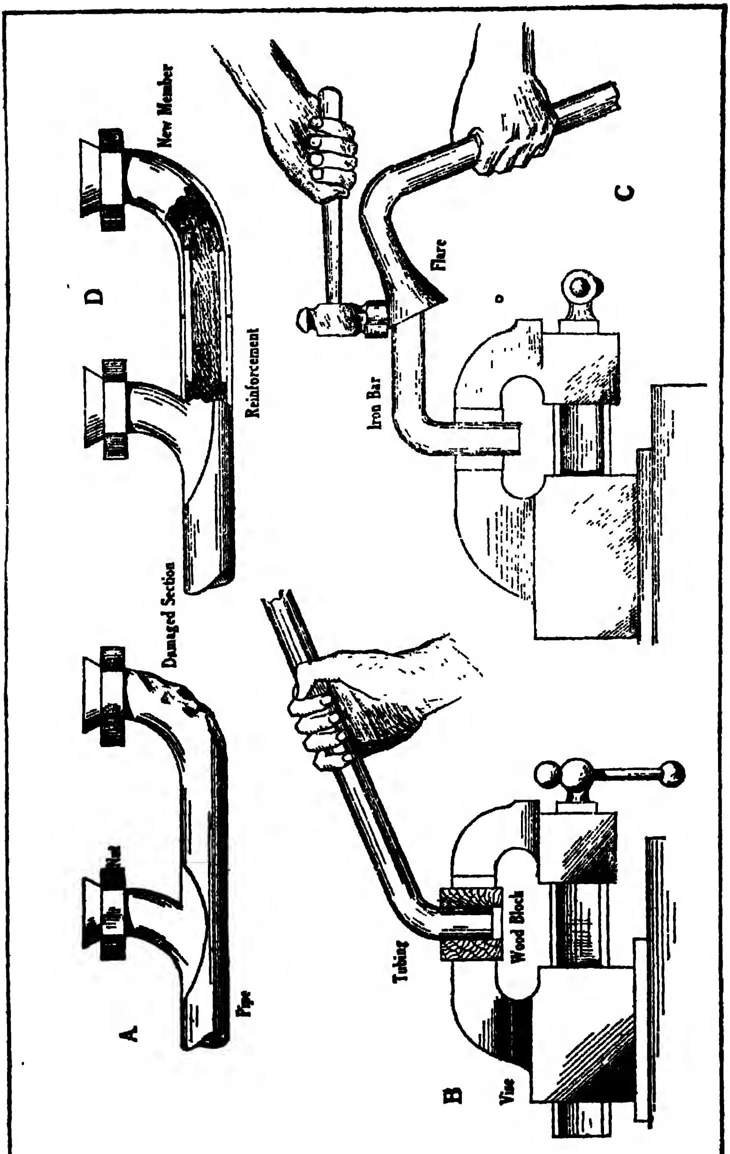


Fig. 178.—Illustrating Procedure in Repairing Damaged Water Manifold.

the water jacket, and was held in place by a nut. In a case of this kind it is cheaper to make a new piece of pipe for the end than to attempt to straighten out the damaged section. The first operation was to bend a piece of tubing of the required size to the proper contour to form the end of the manifold. The end of the tube was plugged with a piece of wood driven tightly in place; the tube was then filled with sand. After heating the tube at the point where it was desired to bend it, it was bent to the required angle by inserting the end into a hole bored in a hardwood block, held firmly in a substantial vise as indicated at B.

The next step after the sand had been removed was to form the bell mouth or flare at the end. This was accomplished as shown at C. A piece of hardwood was shaped a gradual taper and driven into the tube to expand the end slightly. A short piece of round steel rod was bent and held in the vise and the tubing was carefully flared out by continual tapping with a hammer and keeping the tube turning so hammer blows were distributed uniformly around the end. It was necessary to anneal the end of the tube several times during the process. When formed to the proper contour it was again annealed, and while still hot was drawn into its final shape by fitting it to the nipple in the cylinder under the pressure produced by screwing the coupling nut down tight. The concluding operation was cutting off the tubing to the desired length as it had been left longer than necessary to facilitate handling.

In fitting the end of the tube to the manifold it was decided that a re-enforced joint would be superior to any other, and that a neat job would be obtained if the re-enforcement was placed inside of the pipe. The end of the tube and the manifold as well were carefully squared up with a fine file till they butted together perfectly. A piece of brass was rolled into a tube about two inches long, the outside diameter being about the same as the internal diameter of the tubing. This was carefully cleaned and tinned and the inside of the tube was similarly treated. The parts were heated and the tube used for re-enforcing was placed inside of the manifold and sweated into place. To make sure that it would not move two small holes were drilled through and pins driven

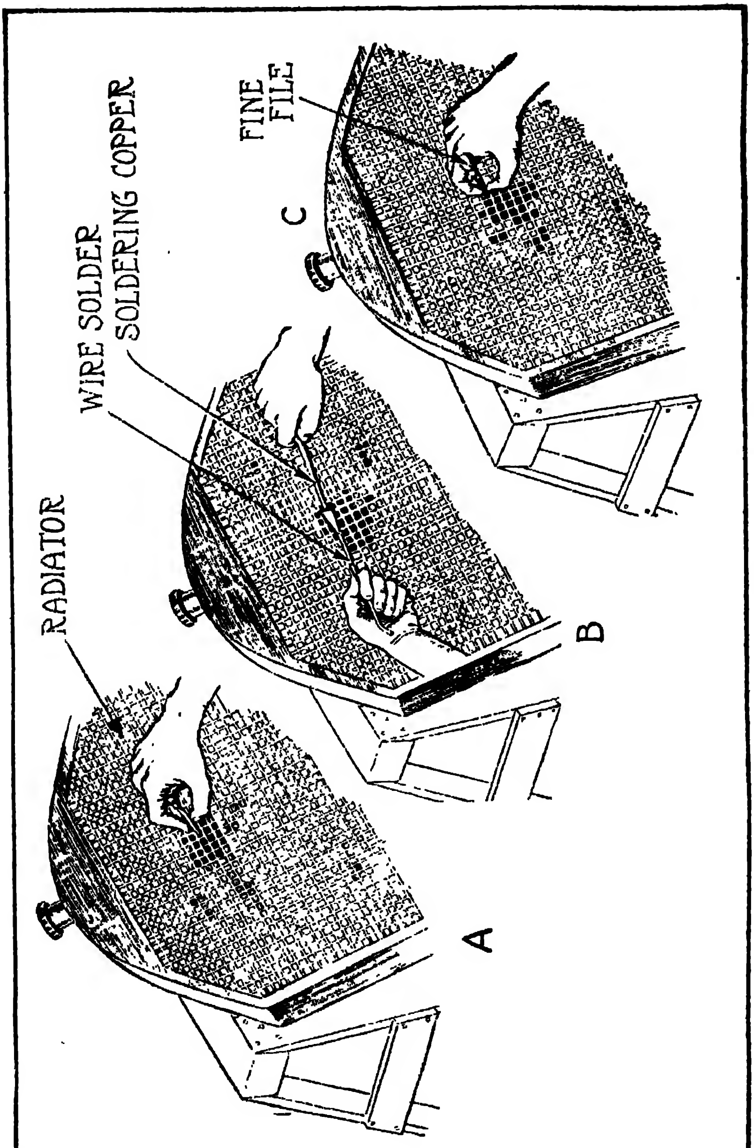


Fig. 179.—Steps in Repairing Leaky Radiator.

in to prevent movement of parts. The short bent piece of tubing was then heated up and slipped over the re-enforcement until it butted against the end of the manifold. To insure that the joints would line up the manifold was connected to the cylinder, then the entire assembly was heated and solder supplied around the joints to insure that the sweating operation would be successful. When completed, the joint had the appearance shown at D, this being a sectional view where the repair was made.

Radiator Repairs.—Radiator repairing is an operation that requires more skill than the average motorist or repairman possesses, unless the leakage is at a point where it may be easily reached. It is not difficult to solder open seams or cracked joints in the upper or lower radiator tank portions, but it is extremely difficult to seal a leak in the radiator interior, especially if that member is of the honeycomb or cellular construction. When the radiators are built, all the joints are treated at the same time by a process of dip soldering, in which the entire section is coated with soldering flux and placed into a bath of molten solder which penetrates all joints. In attempting to make repairs in the interior of a cellular radiator by using the usual form of soldering copper, the inexpert repairman is very apt to start more joints leaking, unless the iron is very carefully handled, and in many cases the radiator is worse than it was before.

A number of compounds is offered for placing in the radiator to seal leaks. These are usually of a glutinous nature and soluble in hot water, the theory being that the solution will solidify on striking the air and seal the crank. Compounds of this nature should never be used in a radiator that can be repaired by any other means, and are a desperate last resort that the owner or repairman has recourse to in making temporary repairs.

If the leak is not a bad one, and is at a point where it can be reached without trouble, it may be sealed as shown at Fig. 179. The first step is to empty all water out of the radiator and remove that member from the frame so it may be tilted as desired to insure that the solder will penetrate to all points of the leaky joints. The first operation is to clean the metal adjacent to the leak carefully with a very fine file or scraper, as shown at A. After the

soldering flux has been applied to all points where it is intended to place solder a very small soldering copper is used to melt enough metal from a piece of wire solder to fill the opening. This is shown at B. The reason the small soldering copper is recommended is because the large one holds so much heat that other joints may be started before the leaky one is properly sealed. The soldering copper used should have a fine point so it can penetrate into the interior of the tube to some extent, if necessary. The final operation indicated at C is to remove the surplus metal from the sides of the tube with a fine file.

If the leak is some way inside of the tube where it cannot be reached handily, it is possible to fill that tube up with some quick drying iron cement and prevent the leak. This cannot be done very often, as if a number of the tubes are blocked up in this way, as is very probable in repairing an old radiator, the available cooling surface will be greatly reduced, as there will be no opportunity for the air currents to pass through the sealed opening. The safest plan is to return the radiator to the manufacturer for repairs, as few repair shops have the skilled workmen or facilities for doing work of this kind.

Defects in Carburetion Group.—Troubles in the carburetor and fuel supply system are usually indicated by overheating of the engine if the mixture is too rich by misfiring or irregular operation if the fuel is not supplied in proper quantities or by loss of power, even though the engine may be running regularly. There are a number of points in the fuel system where defects may materialize besides the carburetor. In fact, the construction of these mixing devices has been refined to such a point at the present time that very little trouble is apt to exist in the carburetor. In order to understand the conditions making for poor carburetion we must first study the carburetion system as a whole to see of what units this is composed, then the defects apt to materialize in the different devices must be enumerated.

In tracing carburetion troubles the first thing to do is to see that there is an adequate supply of fuel in the tank, next to make sure that it reaches the carburetor. If the carburetor is provided with a drain cock this may be opened up, and after the opening

is cleaned out with a piece of wire the gasoline should run out in a stream the full size of the drain cock nozzle bore. If no liquid escapes from the drain, the fuel pipe should be disconnected from the carburetor, taking care to shut off the fuel valve at the tank before this is done, and after the coupling is removed the gasoline should be turned on again to make sure that the fuel feed pipe is clear. If a good stream of gasoline runs out of the feed pipe one may assume that the trouble is at the carburetor. If no liquid issues from the end of the feed pipe, or if it drips very slowly, it is reasonable to assume that the supply pipe is clogged and this must be removed and cleaned out either by running a fine but stiff wire through the bore or by blowing out the pipes thoroughly with compressed air. The trouble may be due to clogging of the strainer or filter in the fuel pipe line as well as constriction of the pipe bore.

Fuel Supply Methods, Gravity Feed.—The simplest of all fuel supply methods is that in which the gasoline flows to the carburetor by virtue of its weight or gravity. Such a system is clearly shown at Fig. 180, which represents the method of fuel supply used on Ford automobiles. It is necessary that the tank or fuel reservoir be carried higher than the carburetor, and that it be placed in such relation to that member that even though the tank is nearly empty and the car climbing a steep hill, the gasoline will still flow to the carburetor. The fuel is carried in a cylindrical tank placed under the front seat in this case, and is joined to the carburetor by a length of flexible copper tubing. A sediment bulb is placed at the bottom of the tank, this having a shut-off valve to interrupt the flow from the tank when desired and a sediment drain cock at the bottom through which foreign matter can be drained off from the bulb where it collects. Water or grit is heavier than the gasoline and will naturally settle at the bottom of the bulb, and as the fuel pipe is attached at the top of the bulb, one is not apt to have water or other foreign matter enter the carburetor float chamber. As an added precaution, a gauze filter is placed at the outlet to arrest any light particles, such as lint, which might be floating in the gasoline and which would not settle to the bottom. The flow from the tank to the carburetor float chamber and

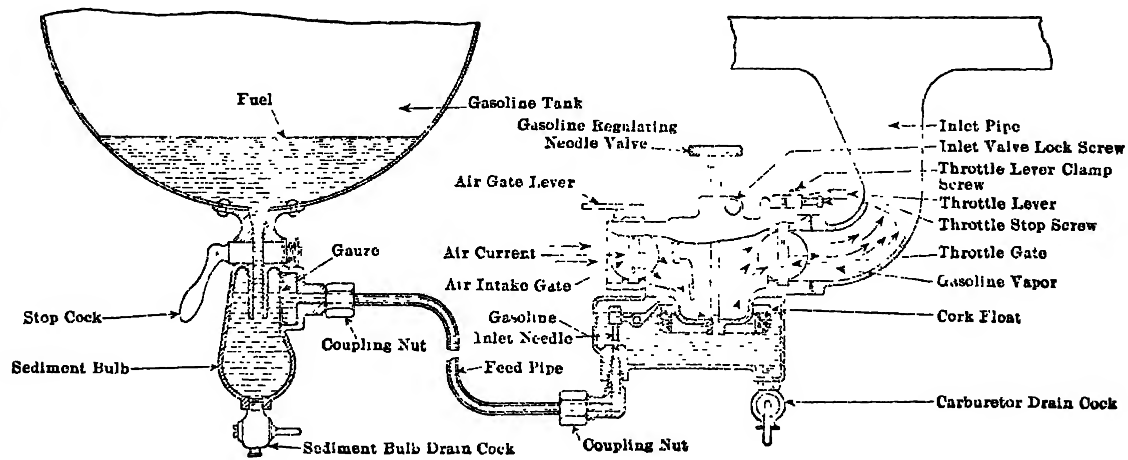


Fig. 180.—The Ford Carburetion System.

the internal construction of the carburetor itself is so clearly shown that further description is unnecessary.

Sometimes when the tank is placed under the seat and it is not possible to place the carburetor low enough to insure positive feed at all times, the tank is arranged so that air pressure will be pumped in to displace the liquid. A system of this nature is shown at Fig. 181, though the pressure piping is not indicated. It will be noticed that the bottom of the carburetor and the bottom of the fuel container are about on a line when the frame is level. If the car is ascending a gradient the carburetor will be higher

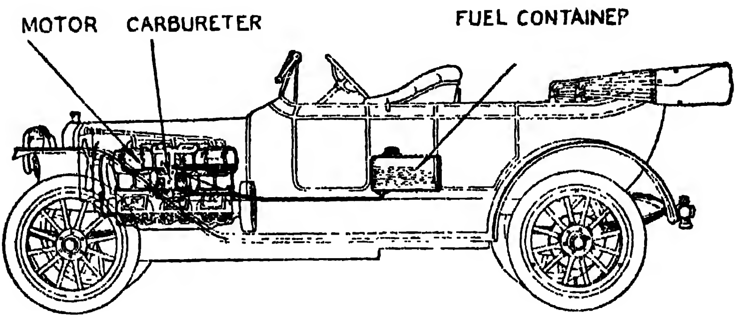


Fig. 181.—Fuel System in which Gasoline Tank is carried Under Front Seat.

than the tank and pressure will be necessary to force the liquid through the pipe lines. Many of the 1915 cars have a gasoline tank in the cowl at the front, just back of the dashboard. When this tank location is used it is possible to employ the gravity feed system without placing the carburetor very low.

Stewart Vacuum Feed and Air Pressure Systems.—Cars having power plants of large capacity or those designed for touring usually carry more fuel than can be conveniently stored in a cowl tank or a container of such size to be placed under the low seats now used. There are two methods of causing the gasoline to flow from a tank when that member is placed below the level of the carburetor. One of these, which is shown at Fig. 182, A, involves the use of an auxiliary tank placed on the dash higher

than the carburetor, which holds a relatively small quantity of gasoline and which is supplied from the main fuel tank either by suction feed as at A, or by air displacement as at B. The system outlined at the top of the illustration has only been recently placed on the market, but is used on many of the latest cars. It is known as the Stewart vacuum gasoline feeding system and calls for the use of a special form of auxiliary tank which is shown in section at A, Fig. 184.

There are some disadvantages to the pressure feed system shown at Fig. 182, B, where the pressure in the tank is maintained to a certain point by a power air pump. If the pressure rises too high, on account of the safety valve sticking, for instance, the excess pressure is apt to cause the carburetor to flood, and even if the carburetor does not overflow, the high pressure often results in excessive consumption of gasoline. Then, again, it is important that there be sufficient pressure all the time to insure a constant supply of gasoline. If a leak starts or the garage man neglects to screw the tank filler cover down tightly after replenishing the supply, it may be impossible to get gasoline to the carburetor. In addition to a power driven pressure pump or exhaust pressure regulator, it is necessary to provide a hand pump for raising the pressure after the car has been standing for some time and the tank pressure is reduced to such a point that it will not force the fuel to the carburetor.

The best pressure system is that in which an auxiliary tank is used on the dash, a float controlled valve similar to that in the carburetor regulating the supply so that this tank always has a uniform amount of fuel therein which is not subject to pressure.

An idea of the complete piping of pressure systems in which the gasoline is fed directly from the tank to the carburetor instead of to an auxiliary tank is shown at Fig. 182, B, as applied to a touring car while the parts of a pressure system used on a roadster model in which the tanks are carried back of the front seat is shown at Fig. 183. It will be apparent that a pressure pipe runs to the top of the gasoline tank and that this is joined to a motor driven pump as well as to a hand operated plunger pump. An air pressure gauge is included in the system in order to indicate

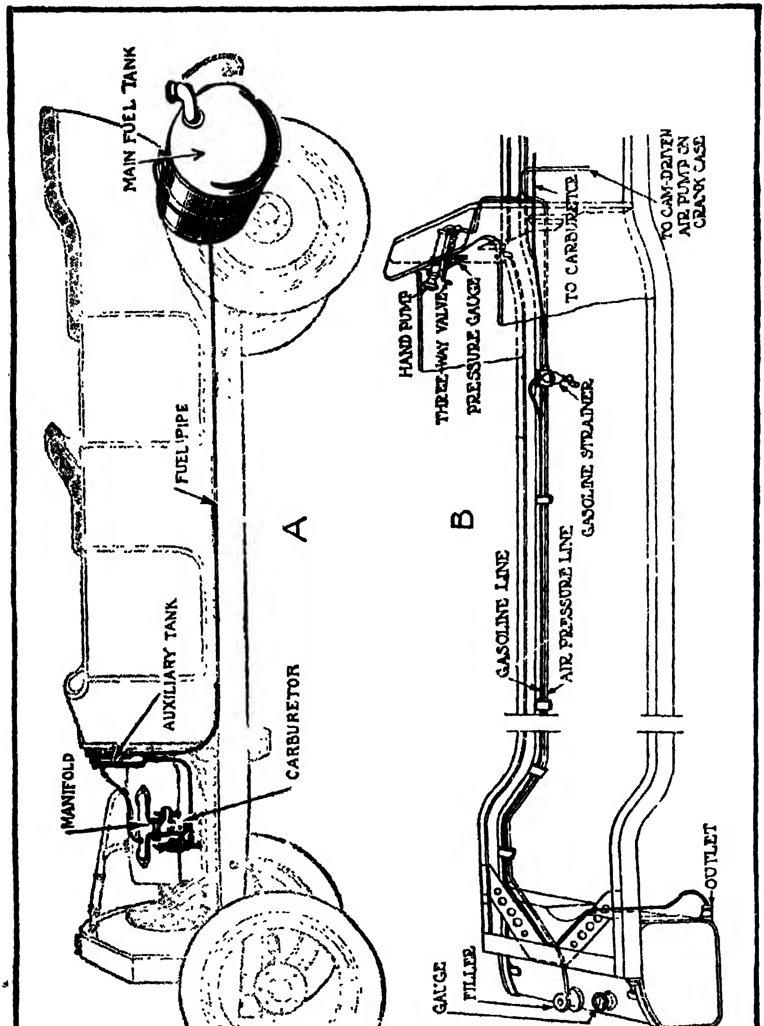
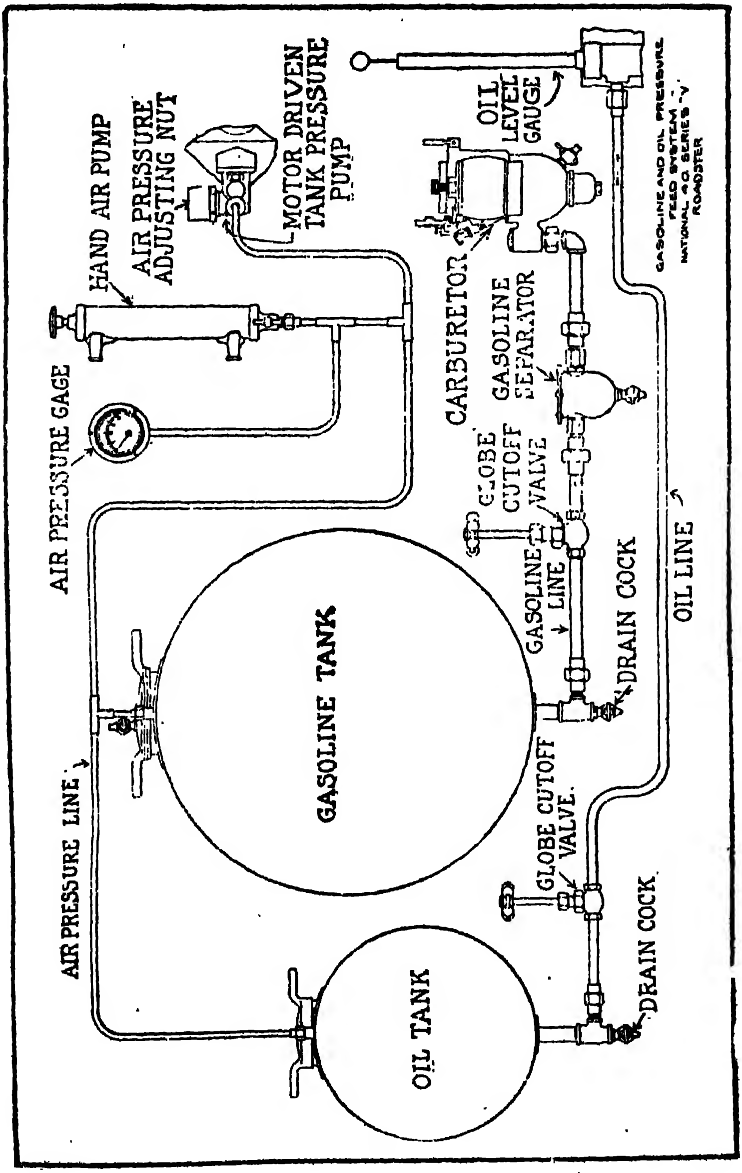


Fig. 182.—Fuel Supply Systems, Having the Tank at the Rear of the Chassis. A—The Stewart Vacuum Tank System. B—Showing Fuel Supply by Air Pressure.

if the proper amount of air pressure is available at the tank. From the tank the fuel passes through the usual form of pipe line, a separator or filter being interposed between the globe cut-off valve and the carburetor. In the system outlined pressure is also utilized to feed the oil from an oil reservoir to the engine crankcase when the proper valve is opened. Ball check valves are placed at the top of the fuel tank in most cases to retain the pressure, and, obviously, failure of this valve to seat or a leak either at the filler cap or in the pipe line will result in enough pressure loss so the fuel feed will be erratic. In event of trouble with the fuel feed one should examine the check valves in the power pump, the three-way cocks below the hand pump must be inspected, the pressure line should be examined at all joints to make sure that these are tight and pipes should be looked over along the entire length for open seams. The filler cap should also be looked at to see that it is tightly screwed down, and that it seats against a suitable gasket.

The construction of the mechanism of the Stewart-Warner vacuum system, which is contained in a tank as at A, Fig. 184, is not difficult to understand. The container is divided into two chambers, the upper one being the compartment in which the gasoline from the tank is first received, while the lower one is called the emptying chamber and supplies the carburetor. This chamber is under atmospheric pressure at all times, and the fuel flows from it by gravity only. Atmospheric pressure is maintained by a suitable vent pipe as indicated. The upper portion of the device or filling chamber is connected to the fuel tank by one pipe, and to the intake manifold by another. In order that fuel may be sucked from the main tank to the upper chamber, the suction valve must be opened and the atmospheric valve closed in which case the float is at the bottom of its travel. When the motor runs the suction of the piston draws gasoline from the main tank and supplies it to the upper chamber. When this is filled to the proper height the float rises to the top; by so doing it closes the suction valve and opens the atmospheric valve. The suction thus being interrupted, the lower chamber is filled by gravity as both chambers are now open to the air.



The Complete Fuel and Oil Supply System of the National Roadster.

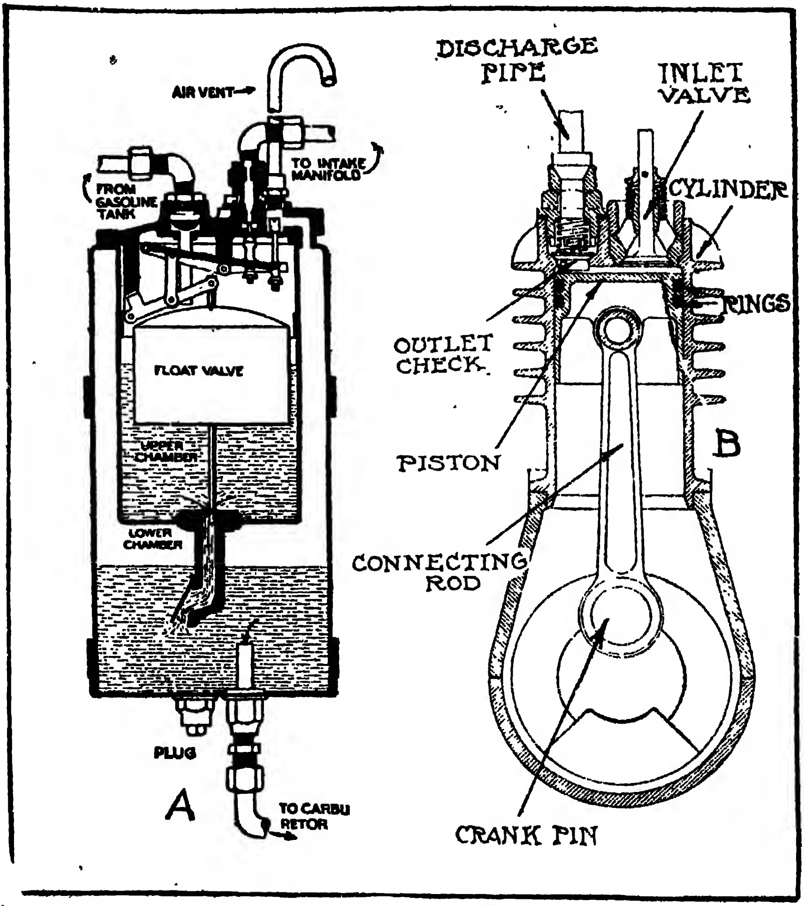


Fig. 184.—Two Methods of Forcing Fuel from a Tank at the Rear of the Chassis. A.—Sectional View Showing Interior Construction of Stewart Vacuum Tank. B.—Sectional View of Typical Motor Driven Air Compressor.

A flap valve is placed at the lower portion of the discharge pe leading from the upper to the lower chamber to prevent the asoline in the lower portion being sucked back into the upper part. It takes about two seconds for the chamber to become full

enough of liquid to raise the float, the amount transferred being .05 gallon. The atmospheric and suction valves are actuated by levers which are interlocked and controlled by suitable mechanica connections with the float. Two coil springs are used so the floa cannot assume an intermediate position; it must be either up o

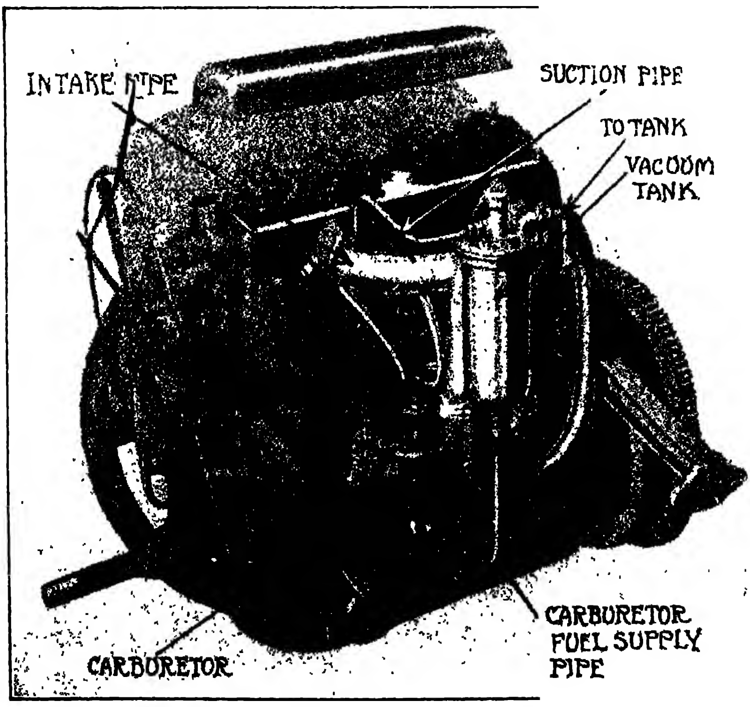


Fig. 185.—Stewart Vacuum Tank Applied to Inlet ... Chevrolet Motor.

down. The only thing that can happen that will permit the vacu to become so low that it will not draw gasoline from the r tank is when the pressure is below four ounces, it being said t this condition can exist only when the motor is running be. 600 R. P. M. with fully opened throttle. If the car is allow to stand long enough so the lower tank becomes empty, it i claimed that a full supply will be obtained after the motor ha

been cranked over four or five times with the throttle closed. This system can be installed on any car and can be placed in a very short time without the use of any special tools. The suction pipe is tapped into the inlet manifold at a point as near to the cylinder as possible while the fuel pipe is attached to a member that runs to the bottom of the gasoline tank. A screen is provided at the end of the fuel pipe to eliminate troubles due to sediment. Since the fuel is sucked from the gasoline tank the filler cap need not be airtight; on the contrary, it should be provided with a small vent so the fuel tank will be at atmospheric pressure. While the usual method of installation is as outlined at A, Fig. 182, where the device is placed on the dashboard, some makers mount it as indicated at Fig. 185. In this case it is attached to the inlet manifold, which means that short suction and fuel supply pipes to the carburetor can be used.

Air Pump Construction.—Where the fuel is lifted from the main container by air pressure, this is obtained by means of a plunger pump in most cases, though sometimes a portion of the exhaust gas is by-passed from the exhaust manifold to the tank through a special form of pressure reducing valve. The construction of a typical air pump that may be used for furnishing air pressure, and that is adapted for placing at any convenient part of the power plant, is shown at Fig. 184, B. In essentials it is not unlike a small gasoline engine. A piston having two packing rings reciprocates in the cylinder which is provided with radiating flanges to assist in cooling. A connecting rod joins the piston to a crank pin in the conventional manner. The pump cylinder head is provided with two valves, one which opens in when the piston goes down to admit a charge of air and which closes as soon as the air pressure inside of the cylinder is equal to that of the atmosphere and is termed the inlet valve. This is carried in a readily removable cage which screws into the cylinder head. The other valve, which is called the outlet check, has an opposite taper to that of the inlet valve, and as a result tends to seat tighter on the suction stroke of pump. On the compression stroke, however, when the air pressure is sufficiently high to overcome the spring resistance this valve will open and permit the air to flow to the fuel

tank. The troubles with a pump of this kind outside of those due to natural wear of the piston, rings and cylinder wall, are invariably valve faults. If the inlet valve does not seat tightly, a portion of the compressed air will escape back through that member. If the inlet valve sticks and does not open the cylinder will not receive enough air. If the exhaust check does not seat positively the pump will not produce any pressure, and trouble may be experienced due to leakage from the fuel tank, as in some cases the pump outlet check is supposed to retain the air pressure in the main container.

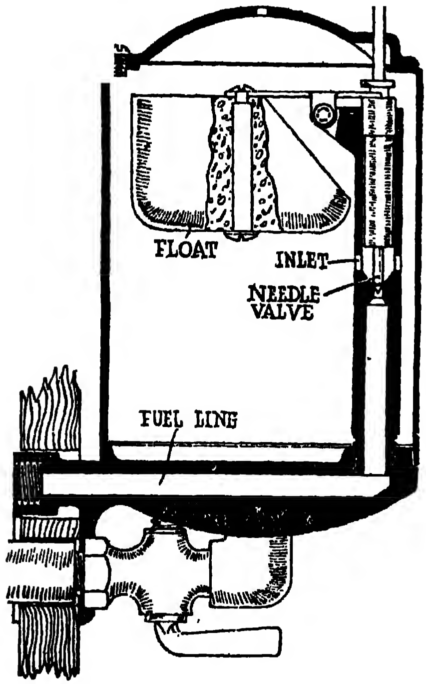


Fig. 186.—Sectional View of Small Auxiliary Tank Placed on Dash and Sometimes Used with Gasoline Pressure Feed System.

Auxiliary tanks are used with the pressure feed system, where it is desired to eliminate the danger of poor carburetion due to excessive fuel feed resulting from too much pressure in the tank. The internal construction of a typical auxiliary tank is shown at Fig. 186. A needle valve admits the gasoline according to the position of the float. When this auxiliary tank is empty the float falls and raises the needle valve from its seat. This permits fuel to flow into the tank from the fuel line. As soon as the proper level is reached the

float rises and seats the needle valve. An auxiliary tank of this nature is subjected to the same troubles as the float bowl of a carburetor is, for the most part, these are flooding due to improper seating of the needle valve, or the float becoming soggy or fuel soaked, and troubles apt to result from deposit of sediment that will interfere with proper fuel flow. This auxiliary tank is in direct communication with the float chamber of the carbureter. The feed from the small tank is by gravity as in the Stewart system.

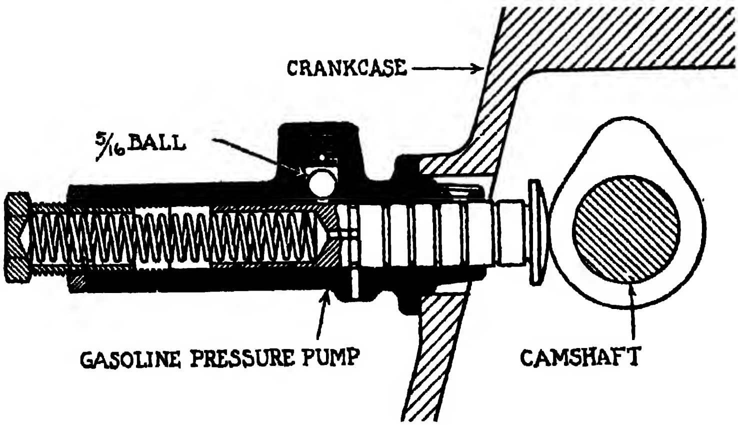


Fig. 187.—Air Pump for Producing Fuel Flow on Jeffery Four Cylinder Car.

Another form of gasoline tank pressure pump of simple design used on the Jeffery automobiles is shown at Fig. 187. This is located on the side of the crank case and is intended to be worked by one of the valve lifting cams. The plunger is kept pressed against the cam by a coil spring. When in the position shown an air inlet in the pump cylinder communicates with the interior by means of an annulus machined around the pump plunger and a passage drilled in the plunger to communicate with the annulus. When the pump plunger reaches the other end of its stroke, which is determined by the height of the cam profile, communication is

made from the cylinder interior by the annulus which now registers with a discharge check of the ball form through which the pressure is delivered to the fuel container. It will be noticed that the pump plunger is provided with a number of grooves which are intended to act as packing members when filled with lubricating oil. These grooves also tend to reduce wear between the plunger and walls by insuring positive lubricity.

Exhaust Gas Pressure Regulator.—While the designs of regulating valves for application to the exhaust manifold vary, that shown at Fig. 188 may be considered a good example of conventional construction. The pressure of the exhaust gas when it issues from the cylinder is too great to permit it to be passed directly to the fuel tank. Besides, it has considerable heat and must be cooled to avoid danger of fire. The exhaust gas enters through a suitable inlet in the body of the device which is bolted to the manifold by a retaining flange. Before passing by the check valve it must first flow through an exhaust gas filter screen which not only is intended to reduce the temperature of the gas but also to prevent particles of carbon or oil passing from the body casting to the check valve portion. The exhaust gas pressure is reduced by allowing a certain portion of it to escape to the outer air through the excess pressure release valve which is kept seated by a coil spring. The pressure of this spring may be altered as desired by screwing the pressure regulating screw in or out. If the screw is turned down the spring is compressed and the gas pressure in the fuel tank will be increased because not so much of the gas will by-pass to the air. If the spring pressure is lessened, the tank pressure becomes less in proportion. The check valve is to keep the pressure in the tank from flowing back into the exhaust manifold.

When a device of this nature fails to function properly one may assume that the trouble is due to a clogged exhaust gas filter screen which does not permit the gas to pass through it, if the trouble is not due to poor seating of the excess pressure release valve or check valve. A certain portion of oil will pass through with the gas despite the filter screen and this may coagulate around the valve seats, either keeping them from seating properly and allowing leakage or by retarding their action due to the sticky

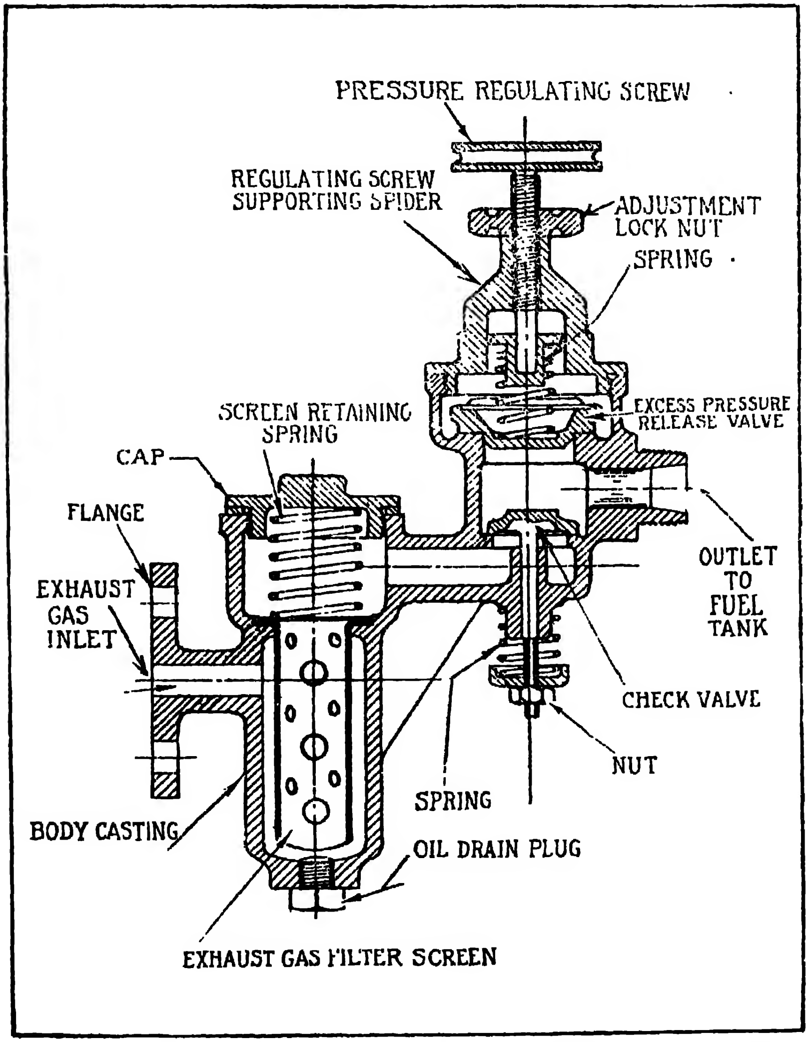


Fig. 188.—Exhaust Gas Pressure Regulating Valve of Conventional Form.

material or gum between the valve and seating. The first thing to look at is the condition of the exhaust gas filter screen. This may be readily removed by unscrewing a cap and lifting out the screen retaining spring. The drain plug is then removed from the bottom of the body casting and all the sediment washed out with gasoline. The check valve and relief valve must also be cleaned out and, if necessary, reground to a proper seating. If the carburetor float chamber overflows, due to excess pressure in the fuel tank, the pressure regulating screw should be turned back or out in order that the release valve will allow more gas to escape to the air, this having the effect of reducing the tank pressure. If the tank pressure is too low, the pressure regulating screw should be turned down to tighten the spring.

Carburetor Troubles.—There are two parts to the usual float feed carburetor and either of these is apt to cause trouble. In the float chamber any defective condition that will prevent the float control valve from seating properly will result in flooding which will be evidenced by a rich mixture. If the passage the valve controls becomes clogged up then there will not be sufficient liquid in the float chamber and the engine will misfire on account of the deficiency in the fuel supply. If the float needle valve is adjusted in such a way that it will close too soon the mixture will be deprived of gasoline on account of the level being too low in the float chamber. About the only trouble that can materialize in a mixing chamber is clogging of the spray nozzle with dirt or water and failure of the auxiliary air valve to open properly. If the spray nozzle is constricted, not enough gasoline will enter the mixture. If the auxiliary air valve opens too much an excessive amount of air will be admitted in proportion to the gasoline, whereas if the valve does not open enough the mixture will be rich.

How to Test Fuel Level.—After a carburetor has been in use for some time, wear may exist at the point of the needle valve or at the needle valve seat, or there may be some depreciation in the fulcrum joint of the lever connecting the float with the needle valve. A good way of testing the float level is shown at Fig. 189, A. The float chamber of the vaporizer is held in a vise and gasoline is allowed to flow from a small can which is joined to the fuel inlet

pipe by a piece of rubber tubing. The gasoline will flow from this can into the float bowl and raise the float as the chamber fills. The level of the gasoline should be just a little below the top of the stand pipe in the mixing chamber. If the level is too high, this will be evidenced by a liquid overflowing at the standpipe, if it

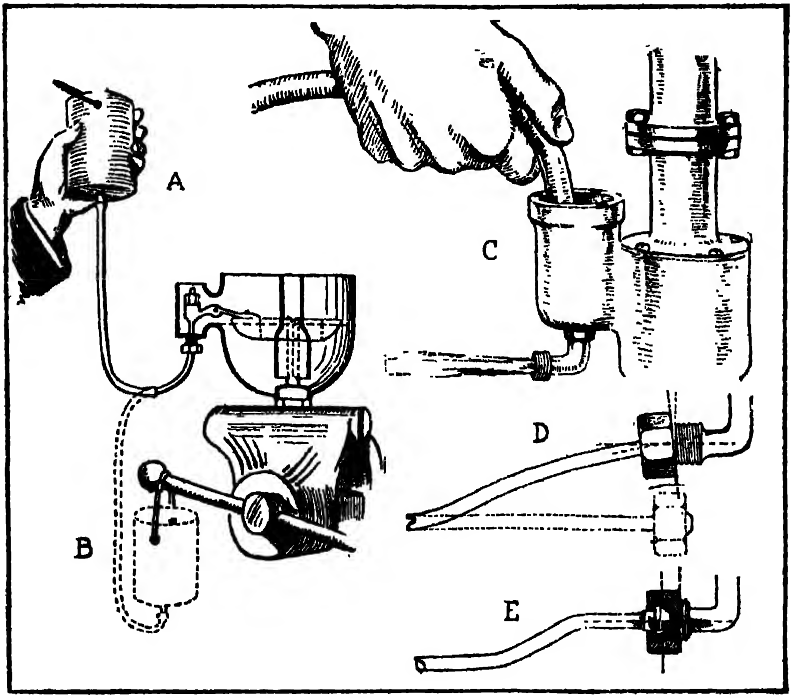


Fig. 189.—Outlining Method of Testing Carburetor Float Level, Clearing Out Clogged Fuel Inlet and Showing Proper Way of Connecting Gasoline Pipes.

is too low this condition may be easily ascertained by inspecting the height of liquid in the jet. If one suspects that the jet is clogged or that the gasoline feed connection on the float bowl is constricted by dirt it is a simple matter to clean the passages out by using a compressed air hose as shown at Fig. 189, C.

The spray nozzle of most carburetors may be unscrewed and

removed for cleaning though this will not be necessary if the compressed air is utilized as shown. The repairman or motorist often finds it necessary to remove the fuel feed pipe from the carburetor and it is often noticed that after this is replaced a slow leak will develop around the joint. It is not difficult to connect the coupling if this is properly done, but it is important that the nut of the coupling is started evenly on the threads of the joints. The nut is often tightened when it is cross threaded and sometimes, even when successfully started it must be screwed all of the way home with a wrench due to cramping of the pipe. The right and wrong ways of connecting a feed pipe are shown at Fig. 189, D and E, the former indicating what to avoid while the latter shows the correct method. The illustration D, shows why the novice often fails to make a proper connection and succeeds only in marring the first two or three threads of the joints. The lower illustration E, shows the joint properly made. The secret is to secure proper alignment of the components before making a connection. If after having properly aligned the parts and screwed the nut fairly tight, the joint should leak slightly, do not exert undue strain on the union in an endeavor to make a tight connection, but loosen it and apply common yellow laundry soap to the threads and screw it back in place.

If a pipe is a short one and there are two couplings, it is well to loosen both unions and start the nuts at each end at the same time, screwing them down together. In this way a tube bent in several places, which tends to shorten it, may be straightened without straining any of the threads on the joints and besides it is always easier to center a loose pipe and start the nut correctly on the thread than to try and line up a pipe fastened rigidly at one end.

It is not always necessary to gauge the distance between the top of the spray nozzle and the fuel it contains in order to determine if the float level is at the correct point. With a 1914 Cadillac carburetor, the level of the fuel is tested by removing the bowl or float chamber from the carburetor, taking out the spraying nozzle and attaching the bowl to the fuel supply pipe. When the chamber is held in a perfectly level position the distance from the

top of the float bowl to the gasoline should be from .6562 inch to .7187 inch. If less than the first named distance, correction may be made by bending down the arm A, shown at Fig. 190, B, slightly. If the float has to be removed, shellac the screw at B, to prevent it working loose when replaced. It is sometimes necessary to grind the float controlling needle valve to a new seat. This may

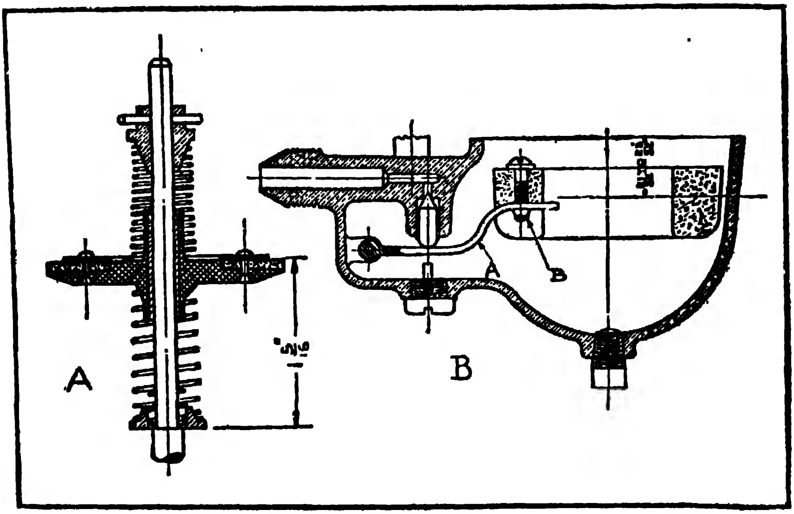


Fig. 190.—How to Set the Automatic Air Valve and Float Lever in 1914 Cadillac Models.

be easily accomplished by using a very fine abrasive, such as grind stone dust.

With many carburetors an auxiliary air valve is utilized, it function being to open as the motor speeds up to supply more ai to the mixture. The suggestion for testing the air valve of th Cadillac carburetor illustrated at Fig. 190, A, is as follows: Re move the small cover over the air valve by taking out two sma screws retaining it to the body of the carburetor. Next, take ou the small split pin near the top of the air valve stem and remov the latter complete with stem from the adjusting nut. Hold th air valve as indicated in the sketch and measure the distance fro

the leather face of the air valve to the underside of the collar on the air valve stem, which should be about $1\frac{5}{16}$ inches. If the distance is more than this it shows that the air valve spring is weak and a new one should be substituted.

Relative to the position of the float it is sometimes possible that too high a level of fuel is due to the float being heavy, which

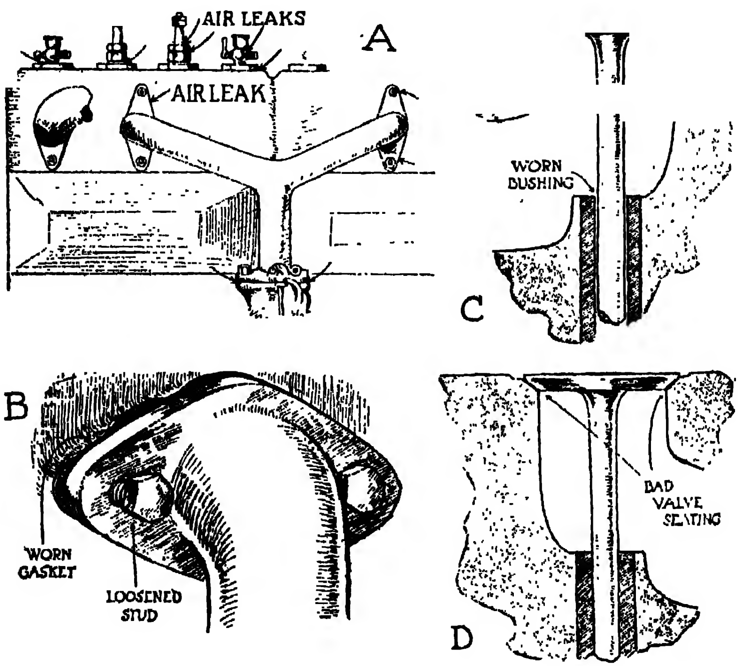


Fig. 191.—Showing Points in Carburetion System where Air May Leak In and Cause Faulty Carburetion.

results when it absorbs a certain amount of fuel. This, of course applies only to cork floats. Before bending the arm to which the float is attached, remove that member and dry it thoroughly. Then give it one or two coats of shellac. In some types of carburetors it is possible to alter the level by adjusting the float and to ascer-

tain when this is correct by comparing the level in the glass float bowl with a line etched on the float bowl wall.

Influence of Air Leaks.—If any difficulty is experienced in throttling down, that is to say, if it is impossible to have the motor run steady with the throttle closed without using a rich mixture, one may assume that the trouble is due to air leaks which dilute the mixture. There are a number of points about a motor where the leakage may be manifested. The main points are indicated at Fig. 191, A. Air may enter through leaky gaskets either where the carburetor fastens to the manifold or where the manifold attaches to the cylinder casting. Leaks at these points are hard to detect as they only occur when the piston is going down in the cylinder to suck in a charge of gas. Air leaks may also be present around the compression relief or priming cocks where they screw into the cylinder, at the valve chamber cap threads or around the spigot joint of the release cock. Leaks are also apt to materialize around the spark plugs where these screw into the cylinder or because of defective packing in the spark plug body itself. Leaks at this point will be clearly evidenced by oil deposits around the leaky portions or if the leak is serious by a hissing noise. Under these conditions it will be evident that unless that carburetor is adjusted to supply additional fuel to compensate for the air leaking in that the motor will run irregularly and that it will only run evenly when speeded up so that the suction draws in the required amount of gasoline. If the mixture is set rich at low speed to compensate for the air leaks, it will be too rich at high speeds.

The air leak may be around a defective gasket as shown at Fig. 191, B, or due to a loosened retaining screw which permits the manifold flange to spring away from the cylinder to some extent or the leak may result from a defective inlet valve stem guide bushing as shown at C. If the exhaust valves do not seat properly, as indicated at E, a certain amount of burnt mixture will be drawn in from the manifold which will mix with the fresh gas and dilute it just as air would. Air leaks may be easily tested by squirting oil or soapy water around the points suspected of being at fault. If any leaks exist they will be noted by bubbles in the liquid. If there is a leak on the suction stroke the liquid will be drawn into a

crevice while the leak will show on the compression stroke by blowing the liquid away from the crack because of the escaping air.

In cleaning a badly sooted spark plug it is sometimes necessary to dismantle it. In reassembling, one may fail to screw down the packing gland tight enough against the shoulder of the porcelain to have that member gas tight. If the leak is around a threaded member such as a petcock or valve chamber cap the faulty piece

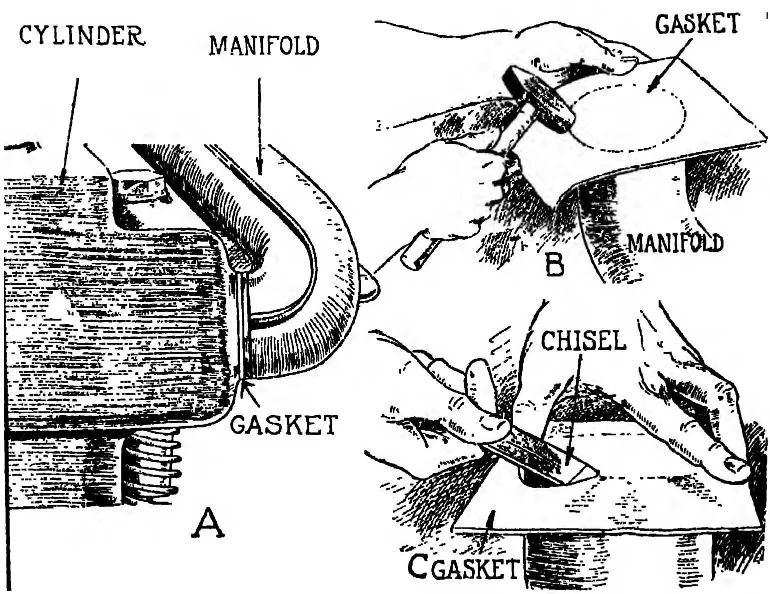


Fig. 192.—Method of Cutting Inlet Manifold Gasket.

should be removed and the threads coated with graphite pipe compound and replaced. If the gaskets or packing members are at fault, it is a simple matter to replace them. The air leaks are sometimes due to blow holes in a cast aluminum manifold or to leaky joints in a brazed, built-up tubular manifold. The only way they can be detected when in these members is by painstaking search with oil or soapy water as previously outlined for testing petcocks and valve chamber caps.

Cutting a gasket is not a difficult operation if this is to be

made of some sheet packing, such as asbestos or rubber. The methods outlined at Fig. 192 for marking out and cutting a gasket by using the manifold itself as a guide, are those generally employed by automobile repairmen. The usual location of a gasket between the cylinder casting and manifold is as shown at A. At B, the method of tamping out the shape of the gasket is clearly outlined, though better results are obtained by using a ball peen hammer instead of the form shown. After the gasket has been marked out, if the material permits, such as can be done with the rubber packings used under water manifold flanges, it may be easily cut to shape by using a sharp chisel in the manner indicated at C.

Notes on Carburetor Adjustment.—The modern float feed carburetor is a delicate and nicely balanced appliance that requires a certain amount of attention and care in order to obtain the best results. The adjustments can only be made by one possessing an intelligent knowledge of carburetor construction and must never be made unless the reason for changing the old adjustment is understood. Before taking up the adjustment of the leading forms of carburetors, a few hints regarding the quality to be obtained in the mixture should be given some consideration, as if these are properly understood this knowledge will prove of great assistance in adjusting the vaporizer to give a good working proportion of fuel and air. There is some question regarding the best mixture proportions and it is estimated that gas will be explosive in which the proportions of fuel vapor and air will vary from one part of the former to a wide range included between four and eighteen parts of the latter. A one to four mixture is much too rich, while the one in eighteen is much too lean to provide positive ignition.

A rich mixture should be avoided because the excessive fuel used will deposit carbon and will soot the cylinder walls, combustion chamber interior, piston top and valves and also tend to overheat the motor. A rich mixture will also seriously interfere with flexible control of the engine, as it will choke up on low throttle and only run well on open throttle when the full amount of gas is needed. A rich mixture may be quickly discovered by black smoke issuing from the muffler, the exhaust gas having a very pungent odor. If the mixture contains a surplus of air there will

be popping sounds in the carburetor, which is commonly termed blowing back. To adjust a carburetor is not a difficult matter when the purpose of the various control members is understood. The first thing to do in adjusting a carburetor is to start the motor and to retard the sparking lever so the motor will run slowly leaving the throttle about half open. In order to ascertain if the mixture is too rich cut down the gasoline flow gradually by screwing down the needle valve until the motor commences to run irregularly or misfire. Close the needle valves as far as possible without having the engine come to a stop and after having found the minimum amount of fuel gradually unscrew the adjusting valve until you arrive at the point where the engine develops its highest speed. When this adjustment is secured the lock nut is screwed in place so the needle valve will keep the adjustment. The next point to look out for is regulation of the auxiliary air supply on those types of carburetors where an adjustable air valve is provided. This is done by advancing the spark lever and opening the throttle. The air valve is first opened or the spring tension reduced to a point where the engine misfires or pops back in the carburetor. When the point of maximum air supply the engine will run on is thus determined, the air valve spring may be tightened by screwing in on the regulating screw until the point is reached where an appreciable speeding up of the engine is noticed. If both fuel and air valves are set right, it will be possible to accelerate the engine speed uniformly without interfering with regularity of engine operation by moving the throttle lever or accelerator pedal from its closed to its wide open position, this being done with the spark lever advanced. All types of carburetors do not have the same means of adjustment, in fact, some adjust only with the gasoline regulating lever while in others the mixture proportions may be varied only by adjustment of the quantity of entering air. We will now consider the construction and adjustment of various makes of carburetors that have received general application and that may be considered as standard forms.

Browne.—At Fig. 193, a novel carburetor of recent development is shown in which no adjusting means are provided and it is said that one size of carburetor will serve all motors, the only

change being that of the effective auxiliary valve opening which is altered for different motor sizes by the use of a specially constructed bushing placed above the valve. It is claimed for this device that it feeds a fuel and air mixture of constant ratio regardless of speed or load.

The Browne is a single-nozzle carburetor with a conventional float arrangement on one side to which the fuel is fed and from

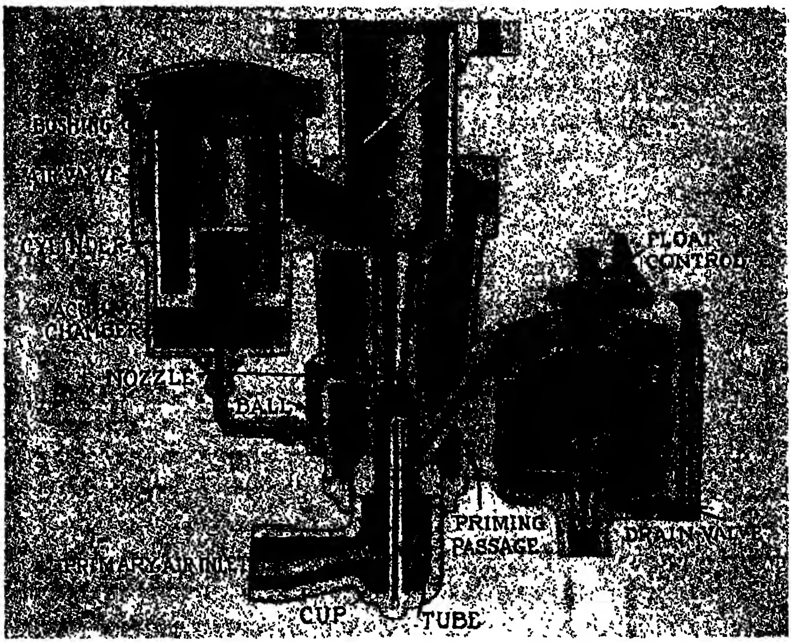


Fig. 193.—Sectional View of the Browne Carburetor.

it the gasoline is run to a nozzle located in the throat of a venturi passage. The air valve is on the opposite side of the mixing chamber and in this construction it differs radically from other types of carburetors. In action the single nozzle with a 7-degree discharge and 30-degree approach feeds the fuel and a primary air inlet surrounding this nozzle feeds the air. In addition, the auxiliary air valve acted upon, it is claimed, both by the vacuum created

by engine suction and velocity of air past the fuel nozzle, feeds additional air in the proper proportion to the speed and load regardless of barometric conditions

As shown in illustration Fig. 193, the auxiliary air valve is located in a chamber which is in communication with the venturi. Underneath the valve is a spring by means of which valve return is obtained. Above the valve is a bushing with a curved surface and as the valve opens or goes downward the valve opening is increased. A cover is provided for the valve chamber. Since the passage from the valve chamber to the venturi ends at a point in line with the nozzle, any vacuum tending to cause fuel flow also will act through the passage on the auxiliary air valve, thus opening it against spring tension. As the vacuum increases the valve goes downward, the opening at the top becomes greater and more air is allowed to flow between the bushing and the valve. Thus the vacuum in the small chamber underneath the valve determines the extent of valve opening, and since for a given vacuum there is a definite fuel flow, for each rate of fuel flow there is a definite valve position.

In order to prevent fluttering of the valve and an excessively rich mixture directly after throttle closing, a ball is placed in the passage leading to the vacuum chamber. This ball is made of bronze and is slightly raised from its seat. When the air valve is being depressed the ball offers no resistance, but when the valve starts to close a resistance is interposed, which prevents fluttering. Also, when the air valve is closed suddenly, due to throttle closing, there is a tendency for the nozzle to feed too much fuel, due to inertia of the gasoline. It is said that the ball retards the movement upward of the air valve in the same proportion as the fuel flow is continued, thus maintaining a constant mixture during the period of throttle closing. In order to prevent any dirt getting between the valve and the cylinder there is produced, by means of the passage at the right of the air valve, a vacuum equal to that on the fuel nozzle. This vacuum keeps the joint effectively clear of all possible obstruction, it is claimed.

The priming lever shown, when pulled, depresses the float in the usual way. This floods the float chamber, but when the fuel

reaches a certain point it overflows through the duct shown, which leads to a cuplike portion in the primary air intake. The fuel is drawn from this cup through the vertical tube shown into the venturi, where it is sprayed by the entering air, which is at high velocity. Another feature of the Browne is the float chamber drain, which is in the form of a needle valve. This makes a simple construction and one quite as effective and more accessible than some of the underneath control cock arrangements.

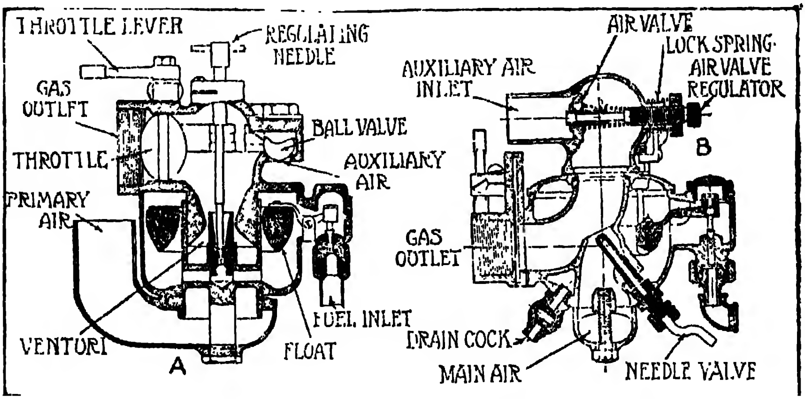


Fig. 194.—American Carburetor Designs that Have Received Wide Application. A.—Kingston. B.—The Schebler Model E.

Kingston.—The Kingston carburetor shown at Fig. 194, A, is of the pattern having adjustment only by fuel regulating needle valve. This is located at the top of the carburetor and screws down into the spray nozzle to vary the size of the opening providing communication between the interior of the jet and the float chamber. The auxiliary air supply is admitted by a series of ball valves of different sizes, these lifting according to the degree of suction to admit more air progressively as the butterfly throttle valve is opened and the motor suction becomes greater. This carburetor is a very easy one to adjust as the mixture proportions are altered by a regulating needle. The float is of cork and controls the small needle valve through a simple lever of the first class.

Schebler, Model E.—This is a very popular form of carburetor

and has been very widely applied, especially in marine service. It was used on many of the early forms of automobiles but has been displaced by improved forms. The amount of fuel drawn into the mixture is altered by a needle valve located at the bottom of the carburetor and which regulates the size of the spraying orifice. The auxiliary air supply is controlled by a leather valve which is kept seated by a coil spring having a tension regulating screw to limit the valve opening. As the tension of the spring is increased, the valve opens less owing to the augmented resistance of the spring. When the spring tension is reduced the air valve will open wider and allow more auxiliary air to flow into the mixture. It will be noted in both of the carburetors shown at Fig. 194, that the primary or main air opening is not variable. This is set to certain proportions determined by experiment when designing the carburetor.

Overland-Schebler.—The device outlined at Fig. 195, is one of the most recent developments of the Schebler carburetor and is the form used on some models of Overland cars. The internal construction is clearly shown at A in the sectional view, while the external parts are plainly outlined at B. The instructions for regulating this carburetor are as follows: First, seat the needle valve, which is indicated as A in the sectional view, by turning the adjusting screw to the right until it stops. Do not use pressure on the screw after it meets with resistance. Then turn it to the left about a turn and a half and prime or flood the carburetor by pulling on the priming lever and holding it for about five seconds. Open the throttle by moving the throttle control lever about two-thirds across the quadrant. Start the motor, then close the throttle slightly, retard the spark, and adjust the needle valve adjusting screw in and out until the motor runs at the desired speed and hits regularly on all four cylinders. When a good adjustment has been secured for low speed with the motor running idle do not alter the needle valve adjustment any more, but make the intermediate speed and high speed adjustments on the dials shown. First adjust the pointer on the intermediate speed dial moving from the figure 1 towards the numeral 3, and setting it about half way between. Now advance the spark lever and open the throttle

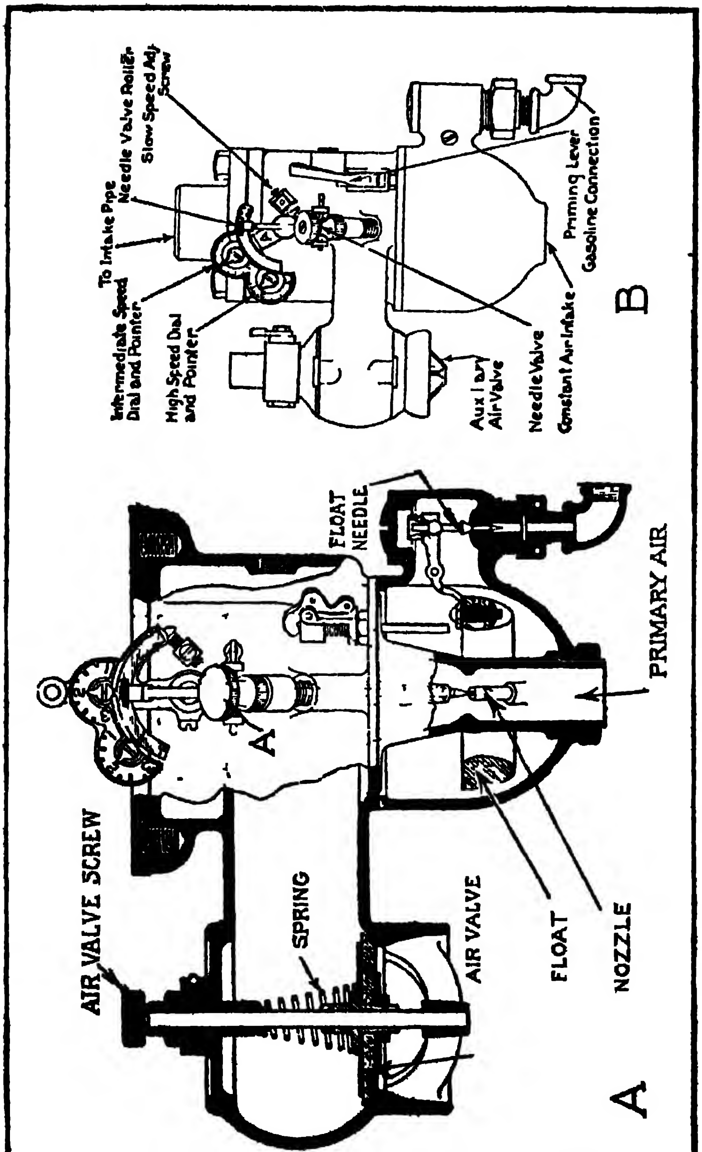


Fig. 195.—Views Showing Construction of Late Model Schebler Carburetor.

so the roller running on the track below the dial is in line with the intermediate speed adjustment dial. If the motor backfires with the throttle in this position, and the spark advanced increase the gas supply by turning the indicator a little more toward the 3 on the dial, or if the mixture is too rich, cut down the gas supply by turning the indicator back towards the numeral 1 on the dial until satisfied that the motor is running steadily at the intermediate position of the throttle. Finally, open the throttle wide and make the adjustment with the high speed dial for high speeds in the same manner as you have made the adjustment for the intermediate speed. In adjusting the carburetor by this method there is a tendency to give too rich a mixture. Therefore it is advisable when making these adjustments to cut down the gasoline needle until the motor begins to misfire, and then to increase the fuel supply gradually until the motor hits evenly on all four cylinders. The auxiliary air valve regulating screw should also be adjusted in order to secure the best valve openings for high motor speeds with the wide opened throttle. For average running a mixture lean in gasoline will give more power and greater speed than a rich mixture, but it will be harder to start the motor than if the richer mixture is employed.

Breeze.—The Breeze carburetor, which is shown at Fig. 196, is of a conventional pattern having mixture proportion regulation by needle valve adjustment for controlling the fuel supply and auxiliary air valve springs tension adjustment for varying the air admitted. The needle valve is controlled by an adjustment screw at the side of the carburetor in one type which is unscrewed to permit the needle valve to rise out of the spray nozzle and screwed in to depress it into the spray nozzle opening and cut down on the amount of gasoline sucked into the mixture. It will be noted that an air shutter is placed in the mouth of the primary air opening, the purpose of this being to facilitate easy starting when it is partly closed to produce great air velocity by the spray nozzle. The Breeze carburetor shown at Fig. 196, B, operates on practically the same principle as that outlined at A, except that it has a side opening through which the mixture is supplied the motor and the gasoline regulating valve is at the top of the car-

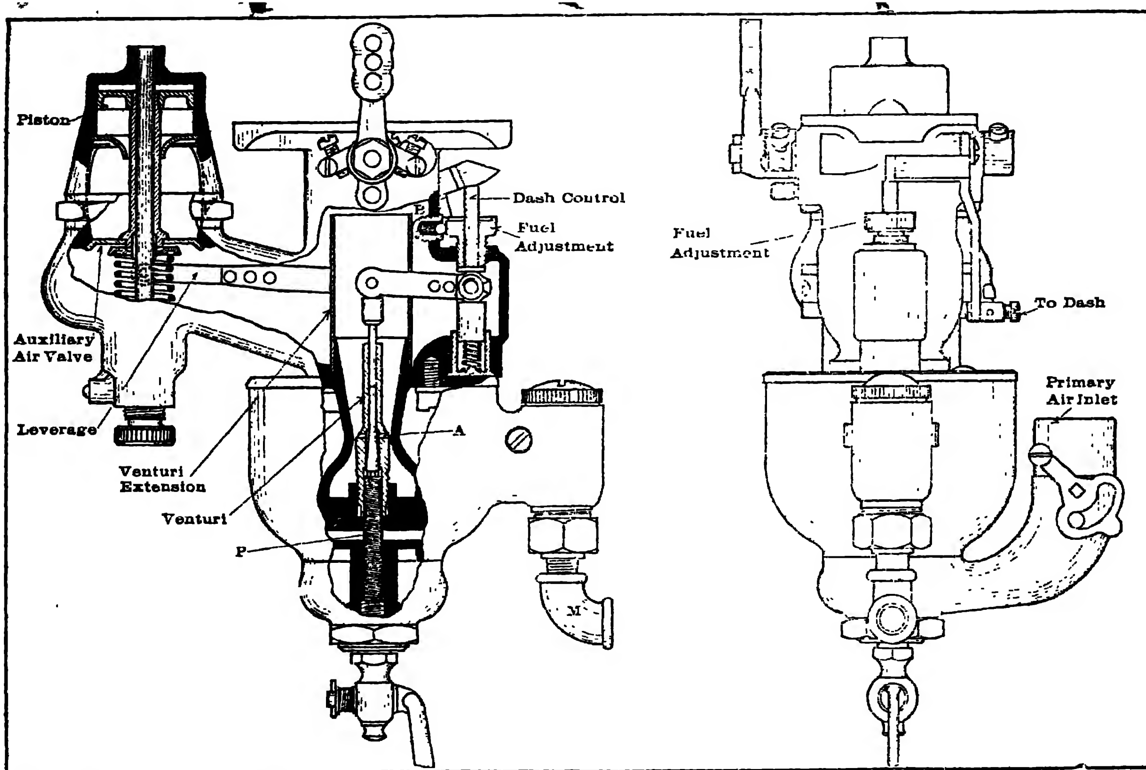


Fig. 195a.—Views Showing 1916 Model Schebler Carburetor Having Mechanical Interlock Between Air Valve and Fuel Regulating Needle, also Dashpot to Prevent Air Valve Fluctuation.

buretor instead of at the side, as is also true of the auxiliary air valve. The fuel supply is regulated by a metal float which operates the lever to shut off the main fuel inlet control valve.

The following instructions are given by the makers of the Breeze carburetors for adjusting their device: Before changing adjustments allow the motor to run awhile, heating it to obtain normal conditions. Advance spark about to center; then open throttle very slightly and adjust your gasoline (figured dial) until the

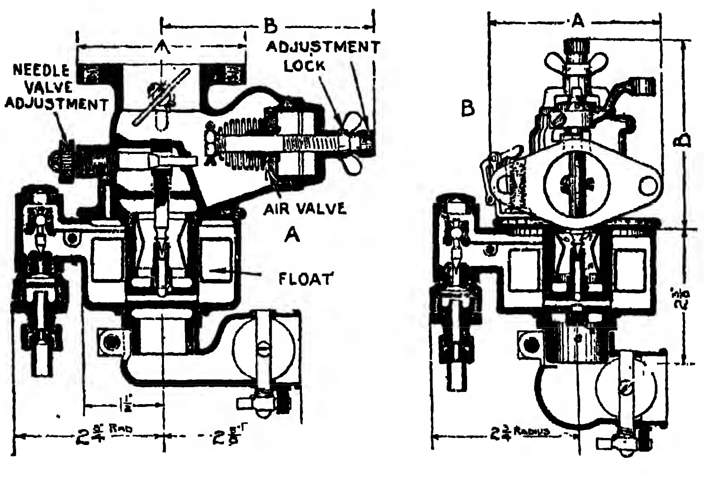


Fig. 196.—Sectional View Showing Construction of Breeze Carburetor.

highest speed is obtained with this setting; then open throttle wide and adjust the auxiliary air by either raising or lowering the adjusting stem on the air valve. If the motor speeds up immediately, auxiliary air is correct; if motor fires back through carburetor on high speed, it indicates *excessive* air, and adjusting stem should be drawn up; if slow in picking up, it indicates a scarcity of air; in that case, lower the adjusting stem. From three-quarters of a turn to a turn and one-quarter is the usual opening of the needle valve required. Screwed all the way down it is closed. To open it turn backwards. *With the throttle and spark*

stationary, the correct position for the needle valve in any case is that at which the engine runs fastest.

If, at the highest speed, the motor picks up perceptibly when the auxiliary air valve is pushed further open, then more air is needed. To adjust the auxiliary air valve, loosen the air valve adjusting wing nut, turn the stem to the left to stiffen the spring and decrease the air, to the right to weaken it and give more air. Be careful, in weakening the spring and giving more air, not to weaken it so much that the valve does not seat. *Air must not get in on low speeds or starting will be almost impossible.* Lock the adjustment securely.

With the carburetor of the proper size for the motor, as indicated by the manifold pipe, if enough suction is not obtainable to open the auxiliary air valve, *with the spring at its lightest tension,* and the motor *at the highest speed,* then a smaller strangling tube should be used. With the conditions reversed from those just described, if the auxiliary air valve spring has to have too great a tension to produce the proper results on higher speeds, then a larger strangling tube is needed to decrease the suction at that point so that the spring can automatically regulate the proper amount of air coming through the valve as the throttle opens for high speeds. The spring in the auxiliary air valve should never be of so stiff a tension that with the throttle half way open the auxiliary air valve remains closed. *The auxiliary air valve should commence to open with the throttle to produce the best results.* After a change of strangling tubes to meet the above conditions, it will be necessary to readjust the gasoline needle valve for low speeds.

To adjust for throttling down the engine to its slowest speed, set the throttle on the steering wheel at its lowest point, loosen the throttle lever lock screw, and with a screw driver turn the throttle stem carefully closed till the engine runs slowly enough to suit you. The slot cut in the stem shows the way the throttle is set. See that all joints between the carburetor and motor are tight. Frequently where the motor picks up slowly with throttle open, a weaker spring will improve matters. Be sure the primer is on the same side of the carburetor as the gasoline inlet, so the primer plunger

presses down the float lever instead of the float. The float feed mechanism is correctly adjusted before leaving the factory. Flooding is caused by dirt on the inlet valve seat, or a poorly seating inlet valve, resulting from improper handling after carburetor leaves factory. Therefore, look for dirt and do not try to change

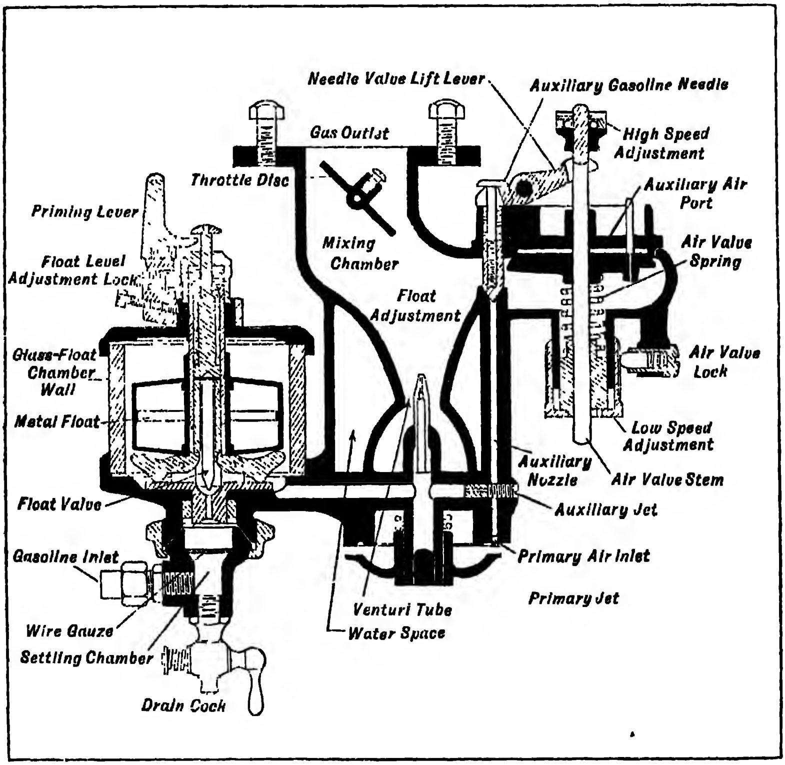


Fig. 197.—Stromberg Two Nozzle Carburetor.

float level. *Never grind inlet valve with emery;* this ruins the seat and the valve.

Stromberg.—The Stromberg carburetor shown at Fig. 197 is a form having two spray nozzles, and with a glass wall float chamber carried at one side of the mixing chamber. In this carburetor the

height of the fuel in the float chamber may be varied by a float level regulation member, and it is not difficult to determine the proper height as a mark is etched on the glass walls with which the level of liquid must coincide. The spray nozzle is provided with a needle valve to regulate the amount of gasoline sprayed into the mixture. The secondary nozzle is controlled by a needle which is raised from its seat when the auxiliary air valve is sucked down due to greater suction produced by increased throttle opening. The valve controlling the auxiliary or secondary jet is lifted by a bell crank and the amount of opening relative to the travel of the auxiliary air valve is determined by the position of the adjustment nut carried on the threaded end of the air valve stem. The amount of air valve opening is regulated by altering the spring tension which tends to keep the valves closed.

A Stromberg carburetor of more recent development, which is known as the H. A., is shown at Fig. 198. In the new Strombergs the motor is fed the proper mixture below 25 miles per hour from the low-speed jet with air from the primary intake and above that speed the auxiliary air valves come into action, and with it the secondary nozzle, which is interconnected with the air valve. When the car is running less than 25 miles per hour the low-speed nozzle only feeds the fuel and above that speed the dashpot comes into play. The piston shown is .01 inch smaller than its chamber, and the fuel entering must work its way around the piston. Integral with the piston is a sleeve to which is attached the air valve. Within the sleeve is the secondary needle, which rests upon a seat shown and has at its upper end a button. The spring within the sleeve holds the needle in position. Should the air valve open, it carries with it the needle and at the same time forces the piston downward against gasoline pressure. However, the needle travels only through the distance AB. This is true because movement downward of the air valve carries the needle, but as soon as the button strikes the nut B it will stop. While the needle is held stationary the valve may continue to move, and so move the seat away from the valve.

In action the piston compensates for lag in the fuel. That is when the throttle is opened the air valve is not allowed to open

quickly, and thus cause poor carburetor action, but instead acts against the fuel in the chamber and opens slowly.

When the fuel is in the chamber and the secondary air valve is opened by increased suction, fuel makes its way up through the holes at the top of the piston, and thence through the sleeve to the tube integral with the air valve. The fuel leaving this tube is

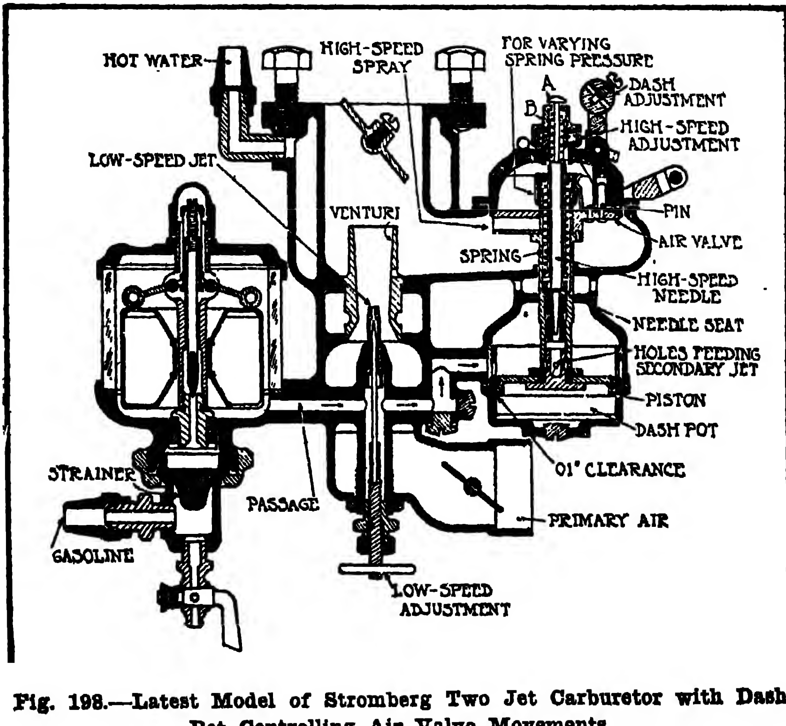


Fig. 198.—Latest Model of Stromberg Two Jet Carburetor with Dash Pot Controlling Air Valve Movements.

carried away with inrushing auxiliary air and forms the high-speed mixture. One important feature of this carburetor is right in this construction which prevents the secondary fuel spray from touching any metal as it leaves the tube, and also getting better mixing by having the fuel meet the air which is at high velocity. The primary nozzle adjustment is in the form of the handle shown and the secondary by means of the knurled nut at the top of the

air valve. The dash adjustment, a series of levers, not only lifts the secondary needle from its seat, but also locks the auxiliary air valve, so that on starting the engine gets a good mixture with the air supply shut off entirely, provided the primary air intake is closed by the butterfly valve.

Holley.—A form of carburetor in which no auxiliary air supply is provided is shown at Fig. 199. This is a concentric float and mixing chamber form and the only adjustment possible is by the needle valve which regulates the amount of fuel passing through the standpipe or spray nozzle. At low engine speeds or when the throttle is closed enough gasoline is drawn from the well I to the strangling tube J to insure sufficiently rich mixture to make for easy starting or to provide just enough gas for idling the motor. All the air must enter through the main air inlet, and before passing out of the mixing chamber it must flow into the tube L by means of the annular passage F, and must brush by the spray nozzle M with considerable velocity, insuring positive feeding of fuel due to the pronounced suction effect of the rapidly moving column of air. In this carburetor the needle valve is set to provide the best mixture when the throttle valve is fully opened. The mixture proportions at all other engine speeds are said to be regulated perfectly by the degree of engine suction due to the peculiar design of the mixing chamber.

Krice.—The Krice carburetor, which is shown at Fig. 200, is very popular in marine work and operates to some extent on the same principle as the Holley carburetor, the difference being mainly in the method of spraying the fuel. Instead of a spray nozzle of the usual pattern, the gasoline is spread in a thin sheet in an annular opening between the bottom of the mixing chamber and the gasoline vaporizer, and as all air passing through the air inlet must sweep across the face of this vaporizer, it is apparent that it will become impregnated with gasoline vapor. The amount of fuel may be regulated by a gasoline adjustment needle, no source of auxiliary air being provided.

Zenith.—The Zenith carburetor shown at Fig. 201 is a type utilizing a compound nozzle instead of the single spray nozzle in the forms previously described. A sectional view through the mix-

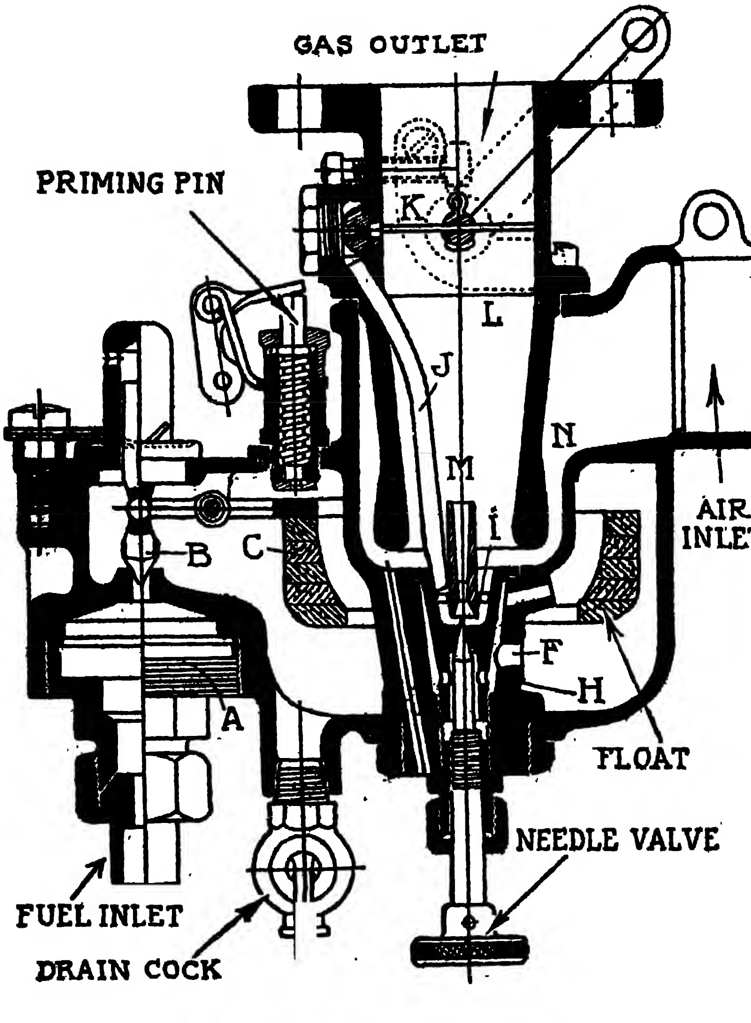


Fig. 199.—Sectional View of Holley Carburetor.

ing chamber is shown at A, while the arrangement of the float mechanism and a sectional view of the compound nozzle is clearly outlined at B. The principle of operation is as follows: The ordinary nozzle, or main jet, is shown at G, and receives gasoline from

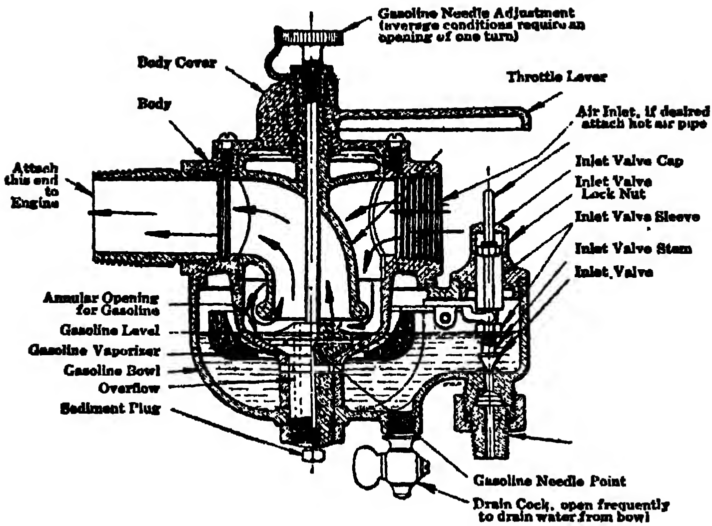


Fig. 200.—Showing Construction of Krice Carburetor.

the float chamber through the channel hole E. It is surrounded by the cap jet H, which receives gasoline, through channel hole K, from a well Q, open to the atmosphere. This well Q receives a measured flow of fuel through the "compensator" I, which, as is easily seen, is not subjected to the suction of the motor, and has, therefore, a constant flow. This compounding of two nozzles, having different and opposite qualities, is the main characteristic of the Zenith principle, and it gives in this new type the same compensation as in the vertical types.

The slow-speed arrangement used in this type differs slightly from the one used previously. It might be termed a "miniature carburetor," and it is made up of the idling tube J, terminating in a cone, into which the idling jet P can be screwed up more or less by means of the knurled adjusting tube O, the air entering through holes in this latter part. The mixture formed at this point follows a channel Z, drilled in the carburetor body, which opens near the throttle; it is there mixed with the air passing through

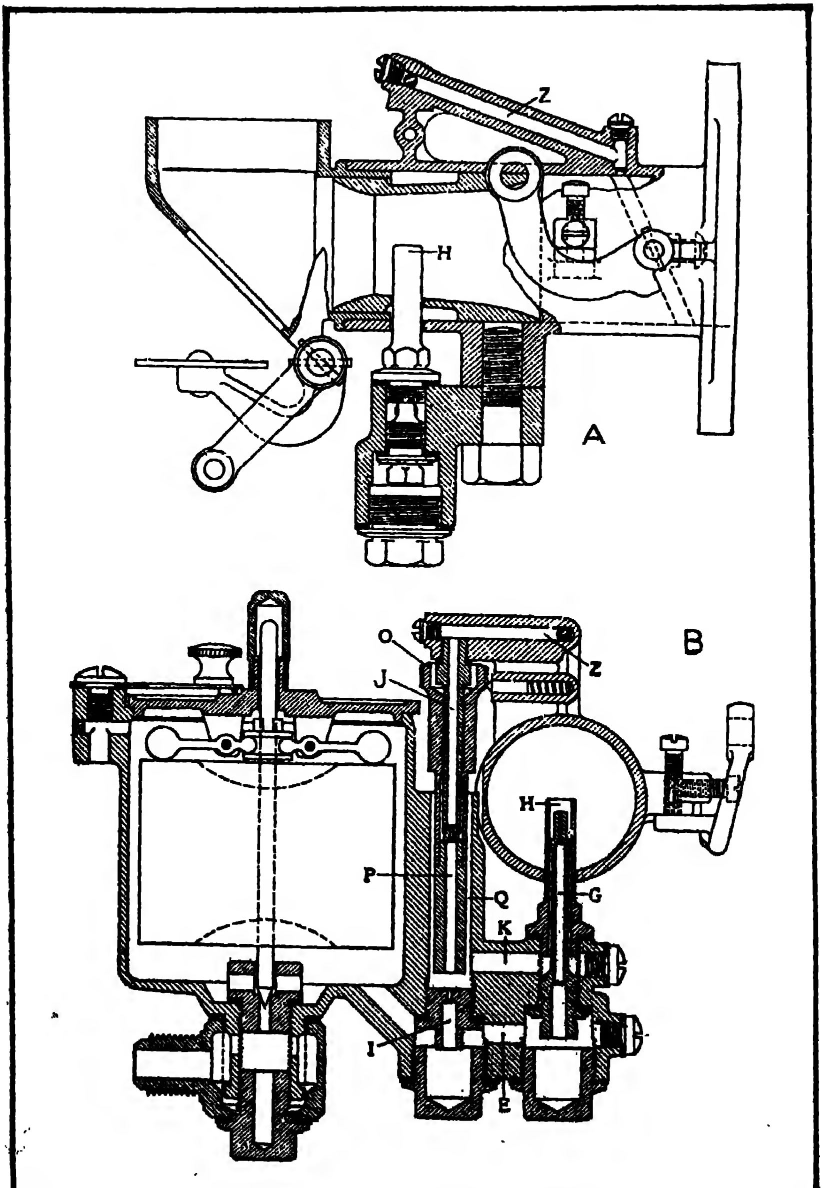


Fig. 201.—View Showing Construction of New Zenith Carburetor.

the throttle. When the throttle is only slightly open the suction there is powerful and atomizes the gasoline perfectly. With a throttle a little more opened the compound nozzle comes into play, and this miniature carburetor has no longer any effect. This slow-speed adjustment does not interfere with the action of the carburetor at medium or high speeds. This carburetor finds its application mostly in the case of monobloc engines where the intake passage is cored in and passes in the center of the bloc, from the valve side to the opposite side. This construction brings the carburetor at a point which is otherwise unoccupied; it removes one obstruction in front of the tappet covers, and, the carburetor being higher than usual, interferes less with the other motor accessories. In most cases at least one bend in the intake passages is eliminated, and it is well known that a bend creates more resistance than the same length of straight path. It shows how hot air, taken also through a cored passage in the cylinder, is conveyed to the carburetor. A little flap, actuated from the dash and shown in the picture in a full open position, may be partially closed, when all the air entering the carburetor will be reheated air; by pulling the control rod completely the flap goes farther and chokes the carburetor, thus causing the formation of an excessively rich mixture, which is useful for starting a cold motor in severe weather.

Rayfield.—The views at Fig. 202 show the Rayfield carburetor, that at A being an exterior view showing all parts to be considered in making an adjustment while the interior construction is clearly outlined at B. To make adjustments on this carburetor the following mode of procedure is observed: First close the needle valve. This is done by turning the fuel adjustment to the left until the screw leaves contact with the regulating cam, which indicates that the needle valve is seated. Then turn the fuel adjustment screw to the right for about one and one-quarter turns. The motor may now be started. For more fuel turn the fuel adjustment screw to the right and to decrease the supply turn it to the left. This adjustment can only be made at retard or low throttle. Having found the right fuel supply for running slowly, open the throttle. If backfiring occurs, turn the high speed adjusting screw to the right, which increases the supply of fuel at open throttle. To

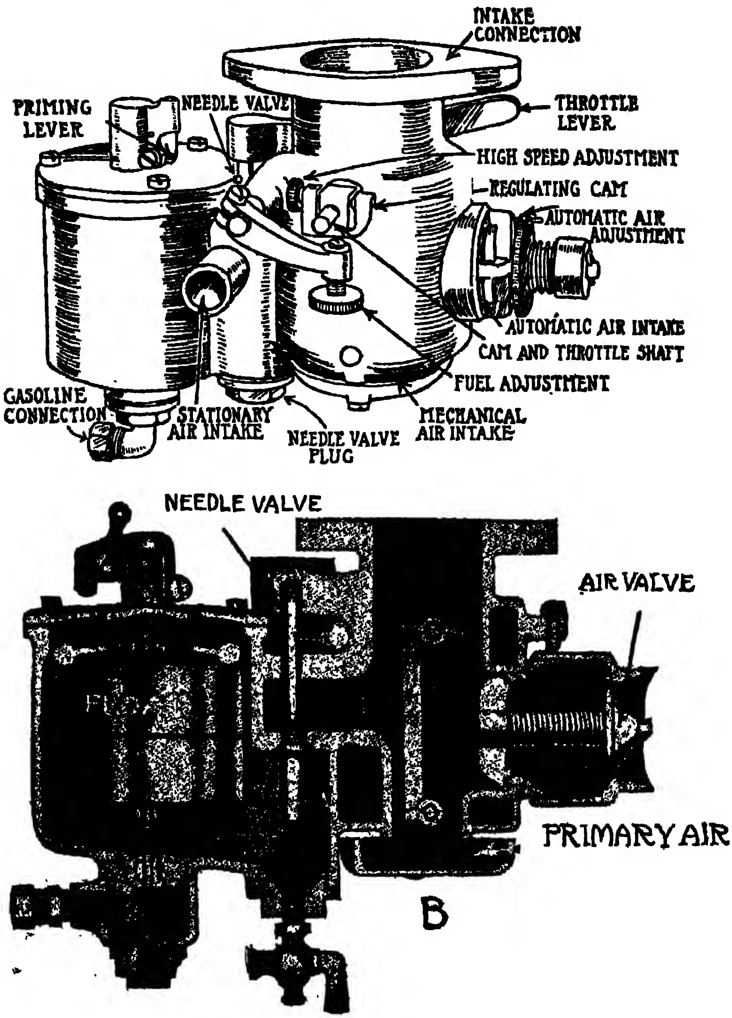


Fig. 202.—Details of the Rayfield Carburetor.

decrease the fuel supply at high speeds turn the high speed adjusting screw to the left. For adjusting the throttle opening use a screwdriver to turn the screw in the stop arm.

After the right fuel supply has been found for both low and high speeds, the throttle should be opened slowly. If backfiring should occur between low and high speed turn the automatic air adjustment to the left. This increases the tension on the springs which control the automatic air valve. The automatic air valve adjustment disk is generally set so that the large spring on the automatic valve has about $\frac{1}{16}$-inch play between the adjusting disk and the cap. After the above adjustments are made, in order to prove that you have proper fuel supply, press with the finger on the automatic air valve, allowing the motor to draw in surplus air. If motor speeds up this indicates that you should use a leaner mixture or that you are not getting enough air. The automatic air valve adjustment disk should be turned to the right until the motor begins to reduce speed or backfires. Then turn the disk back again to the right until the motor runs smoothly. This should be done with throttle about one-eighth open.

Automatic Speed Regulators.—On some forms of automobiles, especially those adapted for commercial work, such as taxicabs and motor trucks, it is desirable to provide means for keeping the motor from exceeding a certain predetermined speed. This is usually accomplished by some form of governor acting on the throttle which regulates the amount of gas supplied to the engine. Some of the governors are driven directly by the motor, others are in mechanical connection with some moving parts of the vehicle. There are very few pleasure cars at the present time that have an automatic speed governing means as the improvement in carburetors has been such that it is possible to secure close regulation of the engine by the usual accelerator pedal or hand throttle lever. A hydraulic governor is used in some models of the Packard truck, this consisting of a chamber carrying a diaphragm against which the stream of cooling water from the circulating pump impinges. When the speed of the engine becomes too great, it is apparent that the flow of cooling water will be more rapid, in which case the pressure against the diaphragm may be sufficiently great to close the carburetor throttle and thus reduce the engine speed.

A form of automatic speed governor which may be mechanically actuated by a flexible shaft connection from the vehicle road wheels

or from some rotating part of the transmission mechanism or power plant is shown at Fig. 203. This is intended to be carried at one side of the intake manifold and regulates the throttle shutter by centrifugal force. The drive shaft mounted on ball bearings carries a governor of such form that as the weights spread apart, due to augmented motor speed, they will lift a plunger which raises a bell crank that transfers the vertical movement of the governor push rod to a horizontal movement of the throttle actuating rod. The throttle shutter stem is in the form of a pinion which meshes with a rack carried by the throttle actuator. The function of the coil spring at the end of the actuator is to keep that member drawn

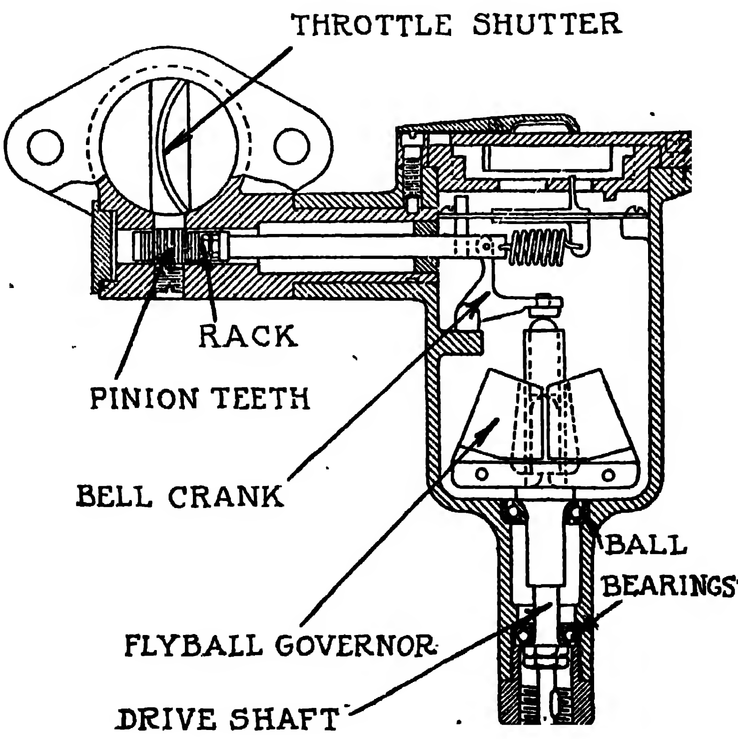


Fig. 203.—Centrifugal Governor Used to Cut Down Gas Supply and Prevent Exceeding Predetermined Motor Speed.

back and the throttle open. When the vehicle speed becomes higher than that for which the device is set, the bell crank will be raised by the weight actuated plunger and the throttle valve closed until the engine speed, which is reduced as the gas supply is diminished, slows down the fast running vehicle. If desired, it is possible to drive the governor from the engine shaft, in which case it will regulate engine speed rather than be actuated by the vehicle speed. An adjustment is provided at the top of the device by which it may be set for various speeds as desired.

Systematic Location of Carburetion Faults.—Having once learned how to adjust a carburetor to supply the properly proportioned mixture for different operating conditions, the repairman will realize that he has found a remedy for many motor ills, because a large proportion of motor troubles, such as misfiring, backfiring in the carburetor, loss of power, etc., are generally due to some faulty adjustment. There are, to be sure, a number of other troubles likely to occur, and while the symptoms are similar to those caused by ignition system faults, the operator who is familiar with carburetor action should have no trouble in locating them quickly and ascertaining positively if they are the result of faulty carburetor action or due to the ignition system. Taking up the various causes which contribute to loss of power, misfiring and trouble in starting the motor, we have: dirt or water in the carburetor, clogged fuel pipe, obstructed spraying nozzle, clogged gasoline filter, leaky metal float or fuel logged cork float, poor or stale gasoline, a loose throttle valve or connection and air leaks in the inlet manifold. If the motor refuses to start and the ignition system is known to be in good condition, the fuel tank may be emptied, the gasoline line shut-off valve closed (it may jar partly or wholly in the "off" position), there may be dirt or water in the carburetor or a choked fuel pipe, or perhaps the fuel level is too low in the float chamber. As a cold motor and stale fuel are the most common hindrances to prompt starting, the first step is to prime the carburetor and fill the float chamber with fresh gasoline. Almost every carburetor is provided with a "tickler," and in most cases priming is all that is needed to supply gasoline enough to insure prompt starting of the motor.

However, if the motor still refuses to operate the trouble is deeper seated and should be found by a systematic search. To locate the trouble without undue delay the various parts of the fuel system should be examined in turn. First, the tank should be looked into to see if it contains sufficient fuel. The filter screen of the carburetor should be removed and cleaned, since the fine mesh is very likely to become clogged with dirt or lint filtered out of the fuel. If the wire gauze is in good condition, examine the pipe line for obstruction. Test the supply pipe by opening the drain cock under the float bowl of the carburetor; if the pipe is constricted, but little or no fuel will be forthcoming. If no gasoline issues and there is plenty of fuel in the tank and one is sure the drain cock is not stopped up, it is reasonable to assume that the supply pipe is choked and it should be removed and cleared out as previously described. If the obstruction is not in the pipe it may be located in the shut-off valve, or perhaps in the fuel line filter.

An obstructed spraying nozzle or jet will sometimes be found the cause of trouble, as the opening in this standpipe is very small, even a tiny particle of foreign matter will be enough to constrict the orifice and so deprive the motor of the proper amount of fuel. Flooding the carburetor will sometimes dislodge the obstruction, but if it does not the spray nozzle should be removed and a fine wire poked through from one end to the other. Compressed air may be used as previously outlined. Fine particles of lint, sometimes work through the strainer and collect into a ball, which floats about and is drawn into the nozzle by the suction of the engine. In cases of this sort the motor will start easily, but invariably commences to misfire, slow down, and finally come to a stop. This peculiar behavior is caused by the greater suction at high speeds which draws the foreign matter in the jet and so chokes the bore, but as the motor slows down and the suction decreases the obstruction will fall away from the jet opening. It is sometimes possible to remedy this trouble by racing the motor and opening the throttle valve suddenly, which will give momentary increased suction, often sufficient to suck the particles of lint through the nozzle opening.

It may be observed that in those carburetors where no fuel regu-

lating means is provided, that the height of liquid in the spraying jet is an important adjustment. The repairman should not be too hasty about altering the position of the spray nozzle in the mixing chamber. If the jet is placed too high the fuel level will be considerably lower than it should be, and while the nozzle will then feed enough gasoline for high speeds, owing to the increased suction, the vacuum created at low velocity will not be sufficient to draw up the required quantity of fuel. On the other hand, if the nozzle is placed too low, the fuel level will be raised unduly and the carburetor will show a tendency to flood. As the proper adjustment can be determined only by experimenting, when the nozzle is so adjusted that the motor will get the proper amount of fuel at both high and low piston speeds the spray jet should not be disturbed again. The only way it is possible to raise the nozzle is by inserting thin washers made of brass or copper shim stock between the spray nozzle and its seat. The only way the nozzle can be lowered is by removing the packing washers, sometimes placed between the nozzle and its seat in the mixing chamber. Alteration of nozzle position is work for the carburetor expert only.

If the repairman notices continuous flooding or dripping of the carburetor, this indicates either a badly seated needle valve, a leaking metal float, or a fuel-soaked cork float. If the float control valve itself is at fault, this is probably due to poor seating. The valve should be carefully ground in by using a small amount of powdered grindstone dust and oil. When doing this work, care should be taken to keep the valve stem in a vertical position, and when finished both the valve and its seat should be smooth and bright. If the valve spindle is bent, remove the float, place the bent spindle on a block of wood, carefully straighten it with a few taps from a light hammer. This applies more to the form of valve passing through the center of the float as indicated at Fig. 201, B, than to the type shown at Figs. 199 or 200. In cases of continual flooding examine a metal float for minute holes or leaky seams, which must be soldered up. Owing to the extreme thinness of a hollow metal float, care must be taken to heat the metal as little as possible. As instructions will shortly be given for repairing metal floats and finding the leak, no trouble should be experi-

enced in making repairs to this member. The use of hard or silver solder, which requires a blow pipe or torch, should be left to those sufficiently skilled to manipulate the heating member properly. In order not to disturb the balance of the float, only a little solder should be used, and care should be taken that none drops inside the float shell.

Mention has been previously made of the way a cork float will gradually absorb the liquid owing to its porous nature and how it will lose its buoyancy when it is fuel soaked. The remedy is a simple one, the cork being placed in a moderate oven so it will be thoroughly dried out and afterward it is given a couple of coats of shellac to make it liquid proof. It will be found that shellac dissolved in grain alcohol will resist the action of gasoline better than that dissolved in wood alcohol. In some carburetors, the float is carried directly by the needle valve spindle, which has the valve at the top so that it may close the fuel opening when the gasoline reaches the proper level If the level is too low the float may be shifted on this spindle to ride at a slightly higher level which permits the float chamber to fill up more. If the float level is too high the float may be lowered on its spindle in order to close the valve sooner or when the float chamber has less gasoline in it.

A cause of trouble in which no control of the motor may be had by moving the throttle lever is due to loose throttle connection. It sometimes happens that the set screw used to fasten the butterfly or disk valve to its spindle becomes loose and allows the shutter to shift about and thus partially or wholly close the opening. In this case the motor cannot be speeded up. If the valve drops into the pipe in such a way that it does not obstruct it to any extent it will be found impossible to slow down the motor as there is no means of cutting off the supply of gas to the cylinder. If the mixture volume is controlled by a sliding shutter as in the Schebler model E carburetor, shown at Fig. 194, B, this may stick in either the open or closed positions, in one case permitting the motor to speed up to its limit, in the other extreme it will prevent speeding up. Troubles with the throttle valve or connections are easily recognized because the motor will refuse to respond to

the movement of the hand lever. An uncommon source of trouble may be a bit of stray waste left near the intake opening or the primary air supply when cleaning the motor. This waste may be sucked into the air opening and will cause trouble by reducing the amount of air supplied the mixture. Air screens also clog with dirt at times.

It is a fact well known to experienced repairmen and motorists that atmospheric conditions have much to do with carburetor action. It is often observed that a motor seems to devélop more power at night than during the day, a circumstance which is attributed to the presence of more moisture in the cooler night air. Likewise, taking a motor from sea level to an altitude of 10,000 feet involves using rarefied air in the engine cylinders and atmospheric pressures ranging from 14.7 pounds at sea level to 10.1 pounds per square inch at the high altitude. All carburetors will require some adjustment in the course of any material change from one level to another. Great changes of altitude also have a marked effect on the cooling system of a car. Water boils at 212 degrees F. only at sea level. At an altitude of 10,000 feet it will boil at a temperature nineteen degrees lower, or 193 degrees F.

In high altitudes the reduced atmospheric pressure, for 5,000 feet or higher than sea level, results in not enough air reaching the mixture, so that either the auxiliary air opening has to be increased, or the gasoline in the mixture cut down. If the user is to be continually at high altitudes he should immediately purchase either a larger dome or a smaller strangling tube, mentioning the size carburetor that is at present in use and the type of motor that it is on, including details as to the bore and stroke. The smaller strangling tube makes an increased suction at the spray nozzle; the air will have to be readjusted to meet it and you can use more auxiliary air, which is necessary. The effect on the motor without a smaller strangling tube is a perceptible sluggishness and failure to speed up to its normal crankshaft revolutions, as well as failure to give power. It means that about one-third of the regular speed is cut out. The reduced atmospheric pressure reduces the power of the explosion, in that there is not the same quantity of oxygen in the combustion chamber as at sea level; to

increase the amount taken in, you must also increase the gasoline speed, which is done by an increased suction through the smaller strangling aperture.

Frost on Intake Manifold and Carburetor.—This phenomenon occurs when the carburetor is delivering a good mixture and there is moisture in the atmosphere. The cold of the vacuum in the manifold and carburetor, created by the suction stroke of the motor, absorbs whatever warmth may exist in the air coming in so rapidly that the suspended moisture in the air outside is condensed and deposited on the outside of the manifold in the same way as a pitcher of ice water "sweats" in summer. The carburetion must be good if this condition takes place. If there is no frost on the manifold, the carburetion may still be good and low grade gasoline be the reason for the non-existence of the frost, as the poor gasoline will not evaporate until it comes in contact with the hot cylinder walls. While frost is indicative of a good mixture, still it shows the presence of atmospheric moisture and in this way is a warning that the air should be *dried out* before reaching the carburetor to obtain the best results from this good mixture. The easiest and most effective method of drying the air is the COLMAC system of a clamp on the exhaust pipe and the air conveyed from it to the carburetor through a flexible tube, as shown at Fig. 208, A.

Soldering a Metal Float.—In repairing or making sheet metal floats, such as are used in the gasoline chamber of the float feed carburetor, one often experiences some difficulty in sealing up the small vent which makes the float air and liquid tight. When a metal float fills with gasoline, it becomes heavier and the float level is altered so it is imperative that the fuel be expelled from the interior and the hole sealed. The usual way to do this is to first locate and enlarge the hole through which the fluid reached the float interior. To locate a leak, the float is held under the surface of boiling water, which evaporates some of the gasoline inside the float and evolves a gas which indicates the hole by escaping through it, because of the pressure inside the float. The hole is then marked, and made larger with a needle drill. Another small hole is made in the float so the interior can be thoroughly cleared out

by air pressure or by placing the float in an oven where the heat will evaporate the gasoline. After the float is emptied, it is necessary to close up the openings. This may be done with an ordinary soldering iron, though most mechanics having the facilities prefer to braze the opening because by this means one can seal it and use a minimum of metal, which is not liable to upset the balance of the float and interfere with the level in the spraying tube. In brazing a joint or vent in a perfectly tight receptacle, the job is often a failure because the air contained in the float becomes heated and produces a pressure that may result in having bubbles in the

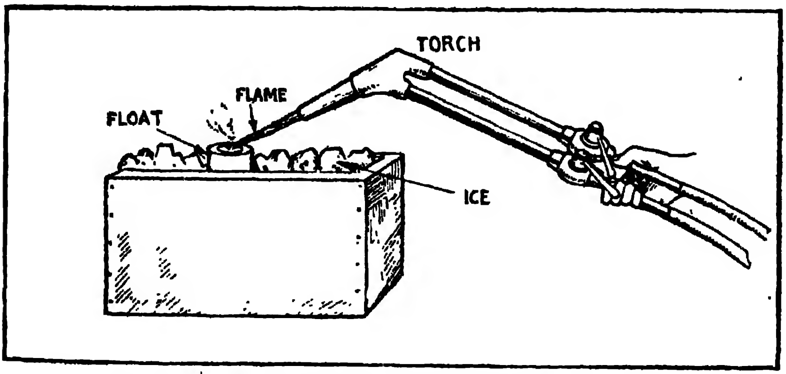


Fig. 204.—Method of Brazing Hollow Metal Float.

brazed seal. To make it possible to close the opening in a positive manner, the copper or brass float may be placed in a box of ice, as shown at Fig. 204, this tending to keep the air contained in the float cool despite the heat imparted to the float by the brazing flame.

Emergency Manifold Repair.—It is not difficult to repair a leak in a built-up manifold of brass or copper tubing owing to the ease with which these materials may be soldered or brazed. When the manifold is a casting, as on the engine shown at Fig. 205, it is not easy to repair a break if the member is of aluminum which is the material commonly used for this purpose. While it is not impossible to solder aluminum, the necessary solder and flux are not apt to be at hand and in addition, the operator must be

skilled in order to manipulate the special solder successfully. The autogenous process, or oxy-acetylene welding may be employed to run new metal in the break and form a permanent repair. All shops are not provided with this equipment, even though they may recognize its value. In fact, in many small shops there would not be enough welding work to make it a profitable investment as the value of the oxygen flame method of burning out carbon is not generally recognized. At Fig. 205, an emergency repair of an inlet manifold that had cracked near the point of juncture between the branches and the stem is outlined. This was accomplished by building a mold of fire clay around the break, leaving a vent at the top through which melted babbitt metal was poured to form a ring around the fracture. This was made wide enough to act as a reënforcement. After it was filed off smooth it was not unsightly, and served to effectively repair the rupture. The same system of repairing might be followed with a cast manifold by soldering a band of metal of sufficient width around the fracture. If the manifold is of cast iron it may be brazed, though if of aluminum it cannot be repaired by a brazing process on account of the heat being high enough to melt the material of which the casting is composed.

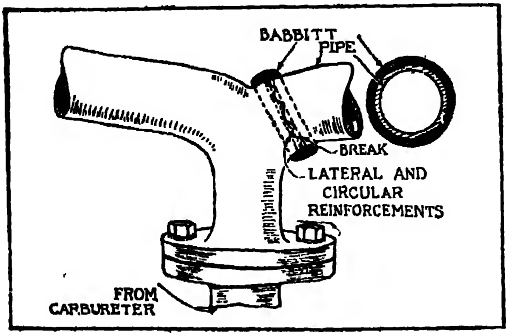


Fig. 205.—Method of Repairing Broken Cast Aluminum Manifold.

Carburetor Installation.—Automobile repairmen are often called upon to install carburetors of different makes from those furnished by automobile manufacturers in order to remedy some real or fancied fault in the original carbureting device. There are many old style cars that have sound engines of good design, but which do not work efficiently on account of using some obsolete form of vaporizing device. The use of a carburetor of modern

development and an up-to-date ignition system often transforms an old engine to one that will give very satisfactory results. While the popular makes of carburetors may be secured in sizes that will fit the widely sold cars, it is sometimes necessary to adapt a special carburetor to an engine for which it was not intended. Perhaps the new vaporizing device is larger than the one it is to replace

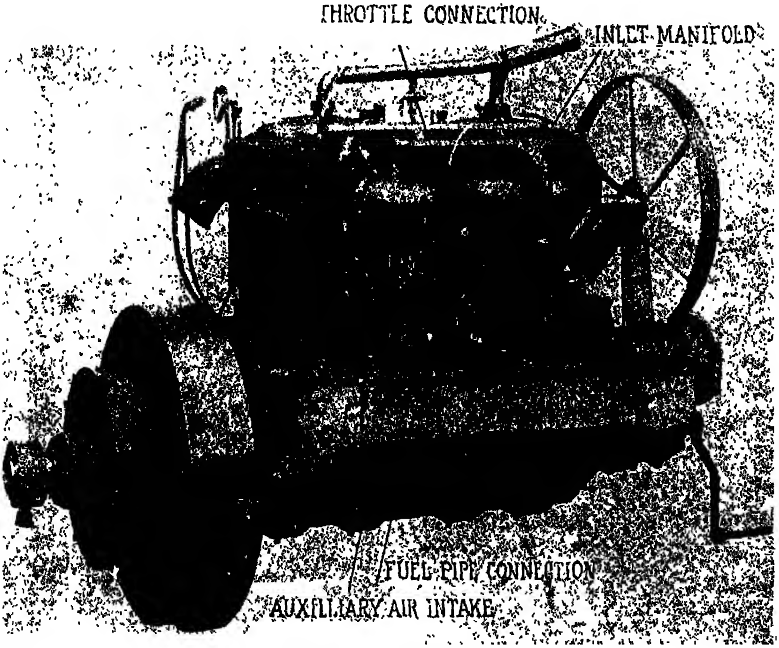
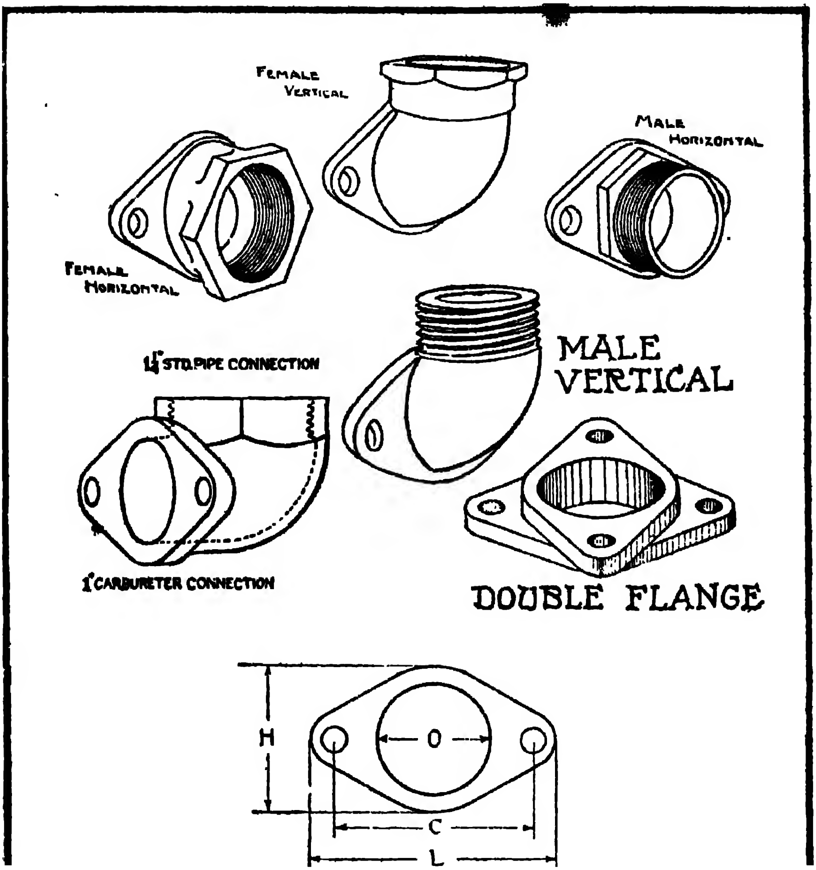


Fig. 206.—Showing Conventional Method of Installing Top Outlet Schebler Carburetor on Short Cast Aluminum Manifold.

or the arrangement of the air valve or float chamber may be such that it cannot be installed in the same way as the one originally supplied with the power plant. A typical carburetor installation is clearly shown at Fig. 206. It will be observed in this case that the cast manifold is of T form, having a very short stem, and that the carburetor is placed close to the cylinders. If it were desired to replace this member with one of different make it might

be difficult to have the new carburetor fill exactly the same space and bolt to the manifold in the same way as the old one.

In cases of this kind some rearrangement of parts would be necessary and special adapter fittings might be needed. A number of these is shown at Fig. 207. Some carburetors have a thread cut on the outlet pipe instead of a flange, and if the old device were of the flange type an adapter fitting would be necessary to enable one to install the new mixer. For instance, if the outlet pipe had a male thread, the female horizontal fitting shown would be necessary. If the outlet pipe were provided with an internal thread, it would be necessary to use the male horizontal fitting. While these are devised for side outlet carburetors, they may be used equally well with top outlet carburetors having a threaded outlet pipe. It is sometimes necessary to couple a top outlet carburetor where a side outlet was formerly used. In this case the female vertical fitting would be necessary with a male threaded outlet pipe, while the male vertical fitting would be needed with a carburetor having an internally threaded top outlet. Fittings of this nature are also made with a flange at each end instead of with a flange at one end and a thread at the other. It is often necessary to use a carburetor slightly larger than that supplied with the engine, or vice versa. In this case fittings having a different size hole at each end are needed. The one illustrated has a 1¼-inch standard pipe connection at one end to receive an externally threaded outlet pipe while the flange is the standard size for a one-inch carburetor. Suppose it is necessary to couple a carburetor having a flange pointing in one direction to a manifold in which the flange was at right angles to that on the carburetor. In cases of this kind the double flange fitting shown would permit of attaching the carburetor to the manifold. While a number of standard dimensions have been proposed for carburetor flanges and corresponding members on manifolds, there is still considerable variance in flange sizes for the same size carburetors. In the lower part of Fig. 207 a typical flange is outlined with the dimensions indicated by letters. The dimensions for different sizes of Breeze carburetors that correspond to the letters may be clearly ascertained from the tabulation beneath the cut.



Details of Sizes.

Size	H	C	L	O
¾ in.	1½ in.	2 in.	2½ in.	15/16 in.
1 "	1¾ "	2 11/16 "	3¼ "	1¼ "
1¼ "	2 "	2 11/16 "	3¼ "	1½ "
1½ "	2¼ "	3 "	3¾ "	1¾ "
2 "	2¾ "	3¾ "	4½ "	2¼ "

Fig. 207.—Showing Adapter Fittings for Use in Fitting Carburetors, Also Dimensions of Typical Carburetor Flange.

It is very important when the low grade fuels that are being supplied at the present time are used to supply some form of preheating arrangement for the primary air in order to insure prompt vaporization. While all of the new engines are being fitted up in this manner, a large number of cars are in daily use that do not have this desirable refinement of detail. When trouble is experienced due to the use of cold air, especially in cold weather, the repairman may often suggest the use of the warm air attachment as a practical remedy for the trouble. A typical attachment of this nature is shown at Fig. 208, A. This consists of a clamp member adapted to bolt around the exhaust pipe and supply the warm air to the primary air intake of the carburetor through a length of flexible metallic pipe. These fittings may be obtained to fit various sizes of exhaust pipe, and for different carburetors. The one shown at A is suitable for the Breeze carburetor, and is installed as indicated at E.

When piping from the fuel tank to the carburetor it is often desirable to include a filter or strainer in the pipe line in order to prevent dirt from passing into the carburetor. This is another refinement that is found on practically all cars of recent manufacture, but which was often omitted on earlier models. Two forms of these filtering devices are shown at Fig. 208. That at C is a form that insures the most positive separation on account of using three filtering screens. The gasoline from the tank enters the intake pipe and follows the course indicated by the arrows through the filter screens and back into the pipe line through the outlet opening. Any sediment or dirt will collect in the lower portion of the device and may be drained off by opening the drain cock. A simpler device operating on the same principle is shown at B. In this case the gasoline enters the lower portion or settling chamber, where dirt and water will fall to the bottom on account of their weight, and only clean fuel that can pass through the wire gauze used as a strainer can flow out of the outlet opening to the carburetor. Care should be taken in installing carburetors to avoid using pipe fittings having sharp bends unless absolutely necessary. Very often all the added efficiency that can be obtained by changing carburetors will be lost when installing a new one due to the

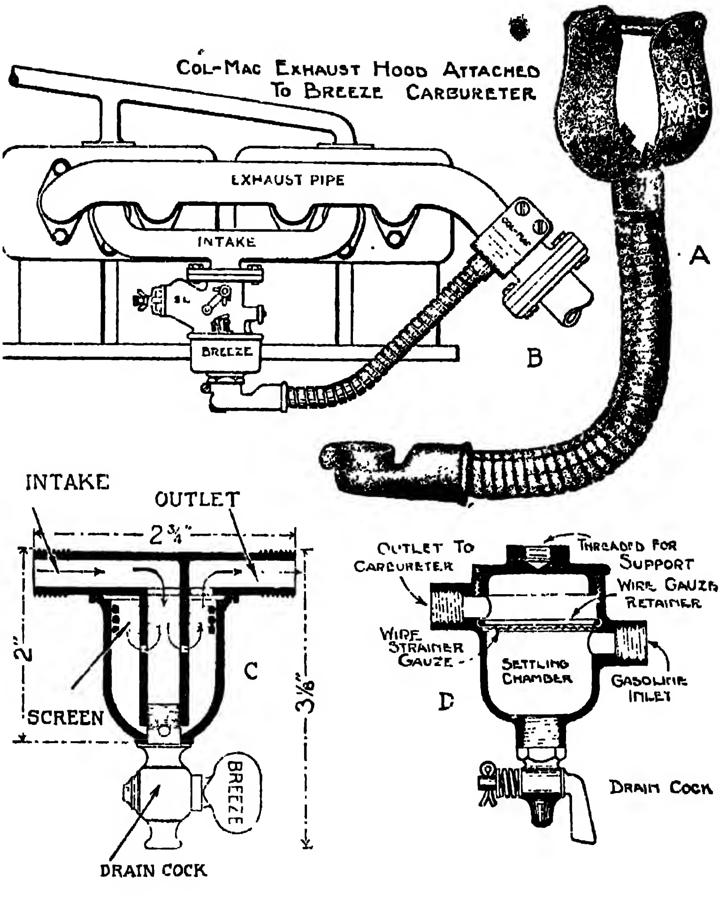


Fig. 208.—Illustrating the Use of Hot Air Connection for Carburetor and Breeze Strainers for Use in Pipe Lines.

use of elbows or other fittings of this nature, which impede the flow of gas. While it is unavoidable in some cases, such as when a side outlet carburetor is to be adapted to a manifold intended only for a top outlet form, endeavor should always be made to secure a carburetor of the same general pattern as that removed. A mistake made by many repairmen when changing over fuel lines

is to use tubing having too small bore or to use material that has a seam running its entire length. Only the best annealed soft copper tubing should be used for fuel lines, and this must be of the seamless form. Hard brass tubing or standard brass pipe is apt to crystallize and break, due to vibration, whereas the soft copper tubing can be bent more easily to clear parts of the mechanism or cross members of the frame, and is not liable to kink up when bending as the hard tube is. Tubing having ⅛-inch (.125-inch) bore will be satisfactory for small engines such as used on motorcycles, but for the range between ten and twenty-five horsepower the tubing should have at least ¼-inch (.250-inch) bore. For larger engines tubing with a bore of $\frac{5}{16}$ inch or ⅜ inch will be sufficient. The piping conveying compressed air or exhaust gas to produce pressure in the fuel tank should be larger than that employed to convey the fuel, the larger sizes being needed with the exhaust gas system on account of its pressure being lower than the air stream from a pump. All fittings should not only be threaded on, but should be soldered as well to insure tight joints. Care should be taken to fasten the fuel pipe to the frame by substantial metal clips, so that it cannot vibrate, which may cause the joints to open up and leak.

Simple Oiling Systems.—Insufficient lubrication or the use of poor lubricating oil will produce the same overheating symptoms that defects in the cooling system do. There is this advantage: when the troubles are caused by poor lubrication, it is very easy to trace the trouble owing to the simplicity of practically all of the modern methods of engine lubrication. A prominent oil manufacturer claims that all of the lubricating systems in use may be divided into ten classes, as follows: No. 1, simple splash; No. 2, constant level splash; No. 3, pump over and splash; No. 4, force feed and splash; No. 5, pump over; No. 6, separate force feed; No. 7, force feed; No. 8, full force feed; No. 9, slide valve motor; No. 10, oil fed with fuel. It is contended that the character of the lubricating system employed is an important point to be considered in selecting suitable grades of oil, but while this is true to a certain extent, it is not necessary to differentiate as closely as most oil manufacturers advise between the various sys-

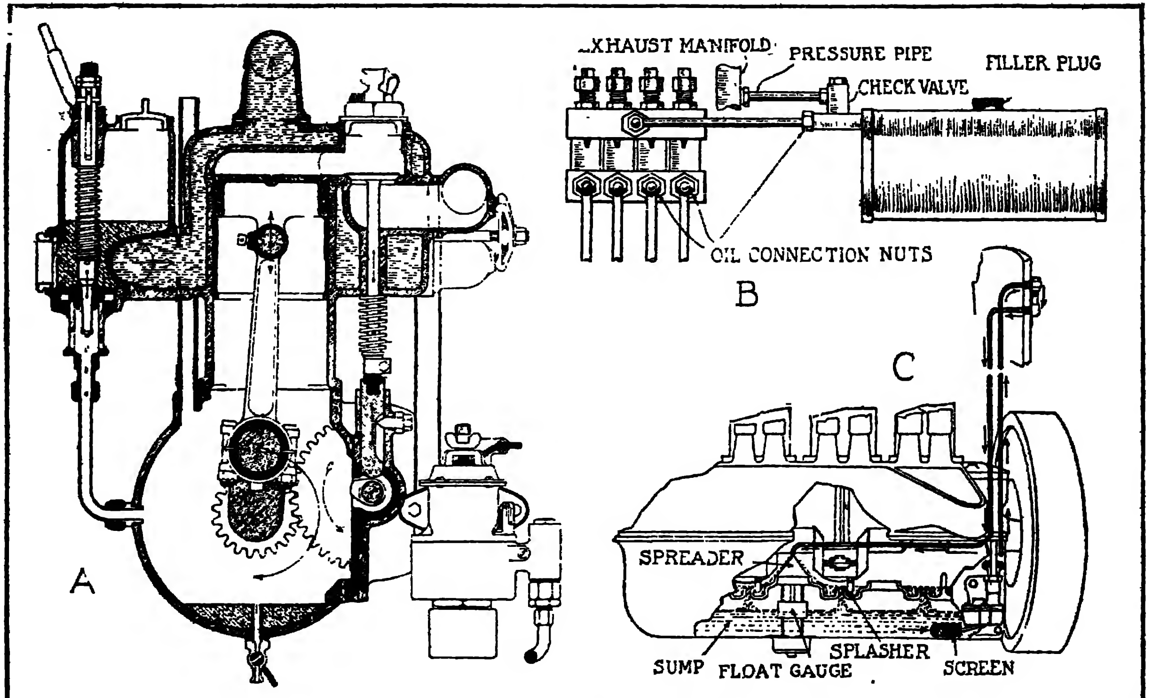


Fig. 209.—Simple Oiling Systems That Have Received Wide Use. A—Method of Supplying Lubricant on Early Hupmobile Models. B—Sight Feed Oiling Systems. C—The Constant Level System Used on Overland Cars.

tems, as careful analysis of their published recommendation sheets shows the same oil to be recommended for engines having totally different lubricating systems in some cases. The writer believes that it is not necessary to divide the lubricating systems into more than two general groups, these being the "circulating" system and the "all loss" system. In the former the oil originally supplied the container or sump of the motor is used over and over again, being circulated to the bearing surfaces in contact by the moving parts themselves, or by some positive form of circulating pump. In the other group the crankcase of the motor is filled to a fixed level. The lubrication of all parts takes place by splash, and the loss is made good by feeding oil into the crankcase from some auxiliary source. In the "all loss" systems the object is to feed the lubricant into the crankcase at about the same rate as it is consumed. After oil has been used for a time in a circulating system it is necessary to drain off the crankcase and thoroughly clean out that member after four or five hundred miles running, as the oil depreciates in value as it is used. In the "all loss" systems it is not necessary to drain out the crankcase as often as in the circulating system, because of the constant addition of fresh oil. The principal group classification may be understood by referring to the simple oiling systems outlined at Fig. 209. That at A may be considered a good example of an "all loss" system in which the oil is allowed to drip into the crankcase from a reservoir to replenish that used in lubrication. It will be observed that the crankcase is filled to a certain height and that the connecting rod will dip into the oil at the end of every down-stroke of the piston. As it sweeps through the oil it throws it about in the engine interior, and thereby lubricates all moving parts. In order to supply more oil when the engine speeds up, the oil feed regulating valve is adapted to be raised by an inclined plane connected with the throttle as it is opened to accelerate the engine speed. This method was used on some of the early Hupmobiles.

Another example of an "all loss" system with individual leads to some of the bearing points from a sight feed lubricator is shown at B. In this case the lubricant is carried in a tank from which it is supplied to the sight feed manifold fitting by displacement

due to exhaust gas or air pressure directed against the oil in the tank. The pipes lead to bearing points in some cases, to the engine cylinders or crankcase in others. The amount passing through may be regulated by adjusting needles at the top of the manifold fitting.

An example of a simple circulating system is shown at Fig. 209, C. In this the bottom of the crankcase acts as a sump or oil container. When the engine is started, a gear pump, which is positively driven by the engine, draws oil from the sump through a pipe connected to a filtering screen. It is discharged from the pump through a tube leading to a sight feed fitting or circulation indicator on the dash. From this it goes to the troughs under the connecting rods, keeping these filled to a constant level, the surplus oil overflowing back into the sump.

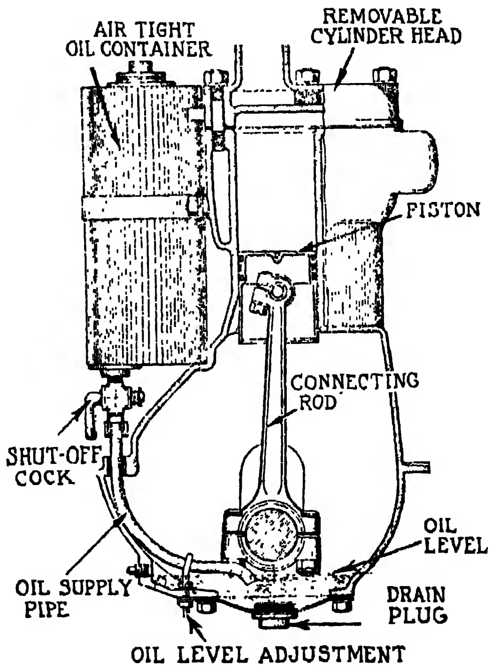


Fig. 210.—Saxon Vacuum Feed Oiling System.

A representative flywheel splash system is shown at Fig. 211, A. In this the bottom of the engine is inclined to form a well in which the flywheel runs. In turning, the flywheel projects the oil which it lifts by adhesion from its periphery tangentially, due to centrifugal force. Part of the oil thrown off is caught by a tube opening into the path of the oil, and is led forward to a main oil duct passing first through an oil feed regulator controlled by the

accelerator. A portion of the oil from the main duct is conveyed to the cylinders, the remainder is directed to the three main bearings. Passages drilled into the crankshaft distribute the oil from the main bearings to the connecting rod big ends. Part of the oil thrown off by the flywheel is deflected against the transmission gears by the gear case cover and part flows to a pocket which lubricates the universal joint. A pipe leading from the universal joint to the bottom of the crankcase insures the return of the lubricant to the bottom of the crankcase.

An "all loss" system in which the feed to replenish the loss is by individual leads from a mechanical oiler is outlined at Fig. 211, B. While this system was formerly very popular, it has been practically done away with at the present time, owing to mechanical complication and liability of trouble. In this system a main oil pump is carried by the oiler casing which serves to house the mechanism, and also acts as a container for lubricant. The pump supplies the top of the manifold fitting through a main feed tube. The various feeds are regulated by needle valves, and after the supply has been set to suit the oil is pumped out of the sight feed glasses by individual pumps through leads which go to the cylinders and to the front and rear crankcase compartment. The idea is to set the feed so that oil will be supplied only in such quantities as are necessary to make up the loss.

At Fig. 211, C, a lubricating system is shown in which oil is pumped from a sump to an external distributing oil tube which leads to the main bearings, and which also supplies a lubricant to the crankcase interior. An internal oil feed pipe is also connected to the pump and is used to fill the troughs into which the connecting rods dip.

The Constant Level Splash System.—The illustration at Fig. 212, A, shows very clearly the interior of an engine in which the constant level splash system of lubrication is used. The supply is carried in the sump integral with the bottom of the crankcase and the height of oil is clearly indicated by an oil level indicator which is actuated by a small float submerged into the oil. As long as there is sufficient oil in the sump the oil level indicator will be at the top of the gauge. As soon as the supply diminishes, the

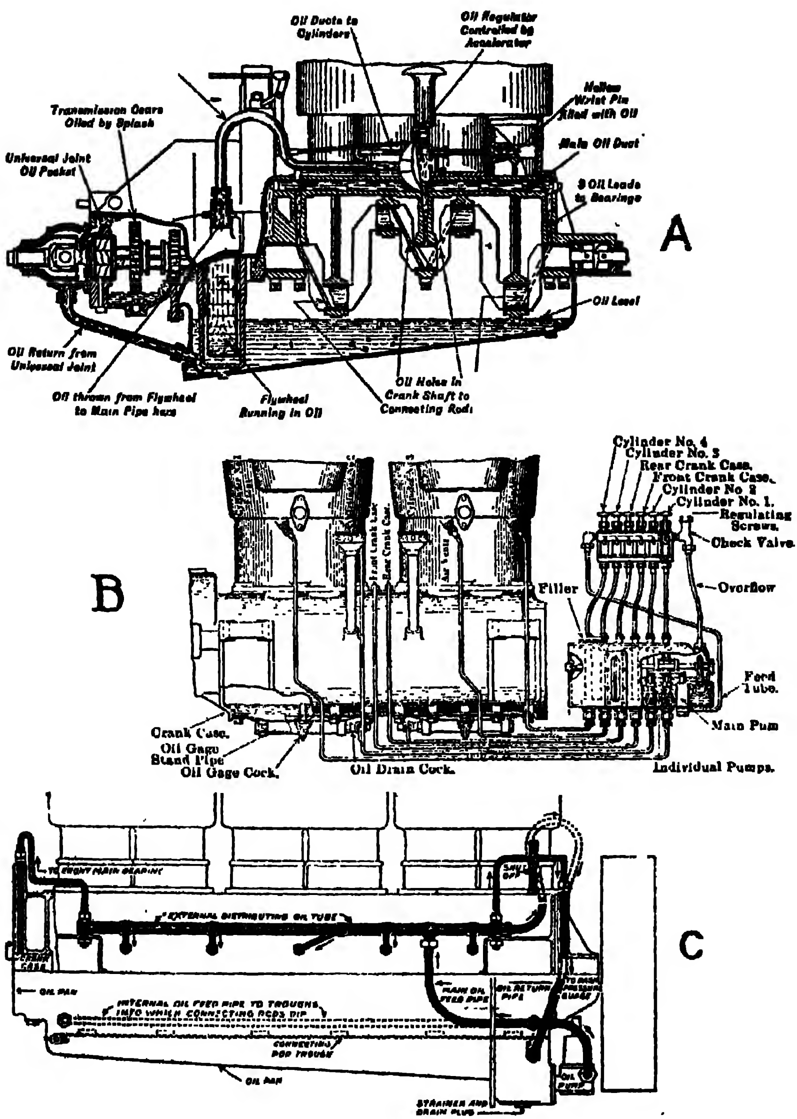


Fig. 211.—Oiling Systems for Multiple Cylinder Engines.

oil level indicator will follow the movement of the float and will show the deficiency in a positive manner. It will be observed that the oil level in the crankcase is determined by the position of the overflow pipe. This can be moved in such a way as to alter the level. The oil is drawn out of the sump by a gear oil pump and directed by means of an integral oil duct to the main bearings of the engine.

Distributing Pump Systems.—The method outlined at Fig. 212, B, is a circulating system in which the various bearing points are kept lubricated by oil drawn from a sump by a geared oil pump, which also combines a distributing mechanism so the oil will be supplied to the various bearing points by feeding each of the oil leads in turn. Some of the leads go to main bearings, others supply the camshaft. The interior of the engine is lubricated by splash as the connecting rods are provided with splashers at the lower end to distribute the lubricant around the engine interior.

Forms of Oil Pumps.—The important element of all the circulating systems is the pump which keeps the oil in circulation. Pumps have been made in various forms, the two main types used at the present time being the plunger and the gear pump. Various applications and designs of pumps are shown at Fig. 213. That at A is a plunger pump, which is actuated by an eccentric strap passing over an eccentric on the camshaft. As the camshaft revolves the pump plunger reciprocates in the pump barrel or cylinder. Each time the plunger lifts the inlet check valve placed directly over the intake pipe opens and oil is drawn out of the sump, first passing through the filter screen, until it fills the space in the pump cylinder left by the upward movement of the plunger. When the plunger descends, a check valve opens and permits the oil in the cylinder to pass out and into a main distributing duct. The splasher or scoop used on most engines and its path through the oil in the trough is clearly shown in this view.

The pump form at B is also a plunger pump, but is the form where a separate pump is provided for each lead from the mechanical oiler. The pump plunger is raised by a cam which is rotated

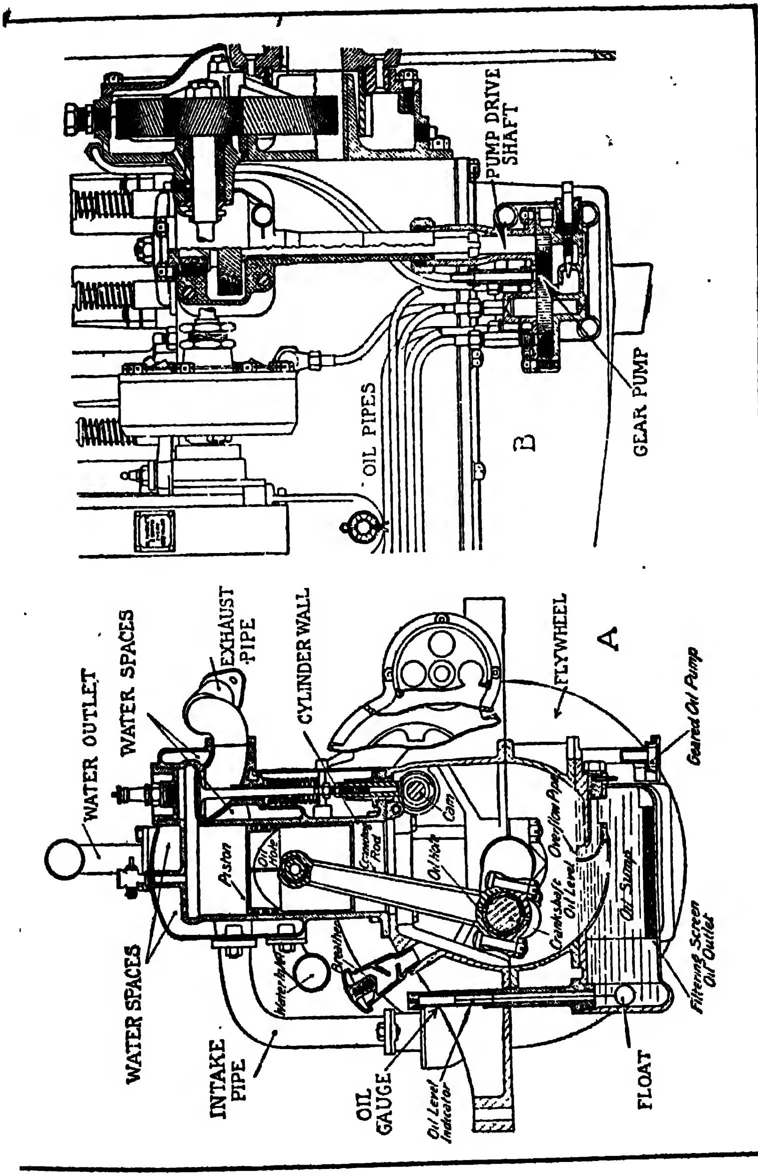


Fig. 212.—Sectional View of Engine, Showing Application of Constant Level Splash System at A. The Oiling System of the Franklin Automobile Shown at B.

by worm gearing. When the pump plunger is lifted by the cam the inlet check valve opens and permits the pump cylinder to fill. On the down stroke the outlet check valve opens and the oil flows through the sight feed fitting, from which it is directed to the bearing points through separate oil pipes, as shown in the system outlined at B, Fig. 211.

A pump of the geared form is shown at C. This operates on exactly the same principle as the water pump of the same pattern previously described. A feature is the use of a relief check valve which will permit the oil to by-pass back into the intake portion of the pump when the pump is turning at such high speed that surplus oil at higher than normal pressure is being supplied. The view at D shows the application of the mechanical oiler shown at Fig. 213, E. This is somewhat similar in principle to that shown at B, except that it is simpler in construction. Mechanical lubricators of this form are used on some 1911 and 1912 models of the Overland car. The pump plunger is actuated by a yoke-shaped member, the horizontal section of which rests on a cam. The camshaft is turned by mechanical connection with the engine, and as it rotates it lifts the yoke and the plunger attached to it against the resistance of a yoke returning spring. When the plunger reaches the top of its stroke, oil will feed into the pump cylinder through the two openings which communicate with the interior of the lubricator. These openings are automatically shut off as soon as the pump plunger starts to descend. An exhaust check plunger opens when the pump plunger descends, and permits the oil to flow past it through the feed tube to the motor. The amount of oil displaced by the plunger depends upon its effective stroke. An adjustment nut is provided which permits one to vary the amount the plunger will descend in the pump cylinder, though it will always rise to the same height as determined by the cam profile. This type of oiler is very satisfactory, and will give but little trouble if clean lubricant is used. Foreign material or wax in the oil will have a tendency to clog the feed tube, but if this should occur it will be indicated by the plunger remaining up. The plunger moves up slowly but drops faster, because of the action of the yoke spring. It is desirable to have the

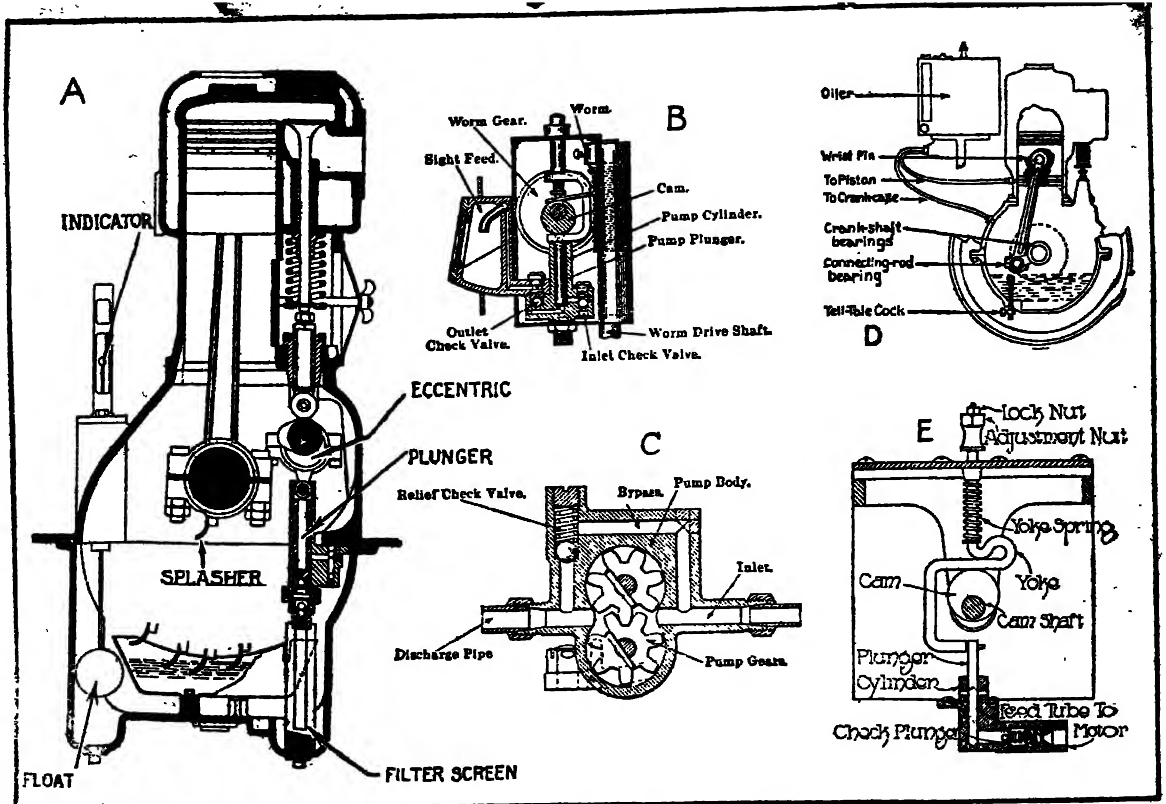


Fig. 213.—Various Forms of Oil Pumps Used to Circulate Lubricating Oil.

plunger come down suddenly, as more force is given to the oil discharge.

The lubricating system shown at Fig. 214, A, is t ... loyed on the Jeffery four-cylinder motor. As is true of all constant level splash systems, the oil container is integral with the bottom of the crankcase, the oil is drawn from that part by the plunger oil pump actuated by the camshaft eccentric, which forces the lubricant through a duct in the crankcase upper portion from which it is directed to camshaft bearings, main bearings and oil troughs into which the connecting rods dip when they reach the lower part of their revolution. The circulation of oil is indicated by a gauge on the dash indicating the pressure. The amount of oil available in the sump or container is indicated by an oil level gauge which is actuated by a float raised and lowered as the supply increases or diminishes. When it is necessary to supply new oil, this is inserted through the breather pipe on the side of the crankcase.

The system used on Abbott-Detroit motor cars is practically the same as that used on the Jeffery except that two oil pumps are used. The view at B is an end sectional diagram showing a portion of the crankcase and sump. The general arrangement of the entire lubricating system may be clearly ascertained by referring to the longitudinal view at Fig. 214, C. As is true of most systems of this nature, the supply of lubricant is replenished through the breather pipe which is provided with integrally cast inclined vanes or ledges to prevent the crankcase compression blowing out the oil mist. The level indicator or gauge is located on the right hand side of the engine, between the second and third cylinders, and the proper level to maintain is between the high and low points of the gauge. It is said that a point about 3/8 inch below the high level mark indicated will give best results. With the level at the proper height there will be about nine quarts of oil in the reservoir, a point which must be considered when the used lubricant is drained out and replaced by new. The system is classified as a constant level splash with positive plunger pumps to circulate the lubricant. These two pumps are driven by eccentrics on the camshaft, one pump supplying a constant stream of oil to the rear main bearing, the other pump feeding the front

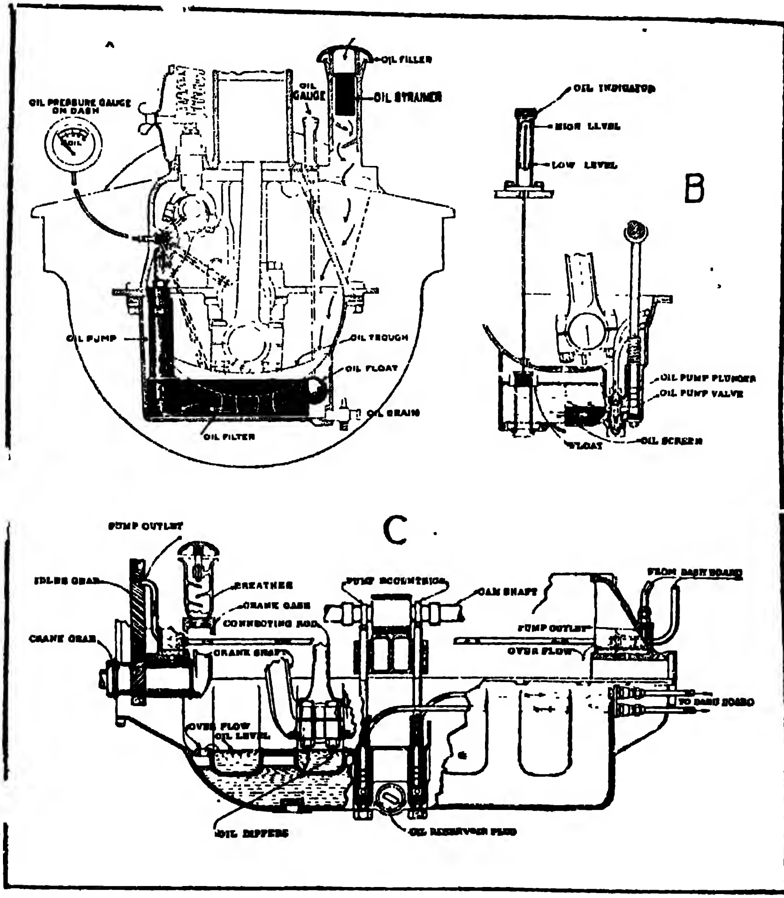


Fig. 214.—Sectional View of Engine Base, Showing Jeffery Oiling System. B and C — Views Showing Double Pump System on the Abbott Detroit Car.

ain bearing and timing gear compartment. The overflow from · bearing drains into four separate troughs, into which the ends the connecting rods dip as they rotate. The lubricant is main- ained at a constant level in this compartment by the use of over- ow pipe, from which any excess lubricant drains into the sump.

All lubricant drawn into the pumps is screened before it is allowed to return to the bearings. The object of employing the separate troughs for the connecting rods to dip in is to prevent the oil from flowing to the rear of the crankcase when the car is climbing hills, or to the front of the crankcase when it is descending grades, as either of these conditions would result in flooding one section of the crankcase and depriving the other portion of an adequate supply of oil. It is recommended that every thousand miles at the most the plug in the side of the lower half of the crankcase be removed and all old lubricant drawn off. It is suggested that if the oil be examined carefully, and particles of metal are found, this indicates bearing troubles. If the oil is filled with carbon particles it may be taken as an indication that gas leaks by the piston rings under pressure of the explosion and burns away some of the oil on the cylinder walls. The screens used to filter the lubricant should be thoroughly cleaned before replacing.

An oiling system similar to that just described, inasmuch as it uses two pumps of the plunger type, is shown at Fig. 215. In this the oil reservoir is divided into three compartments; one of these serves as a main container for the oil, one at the center is filled part way up with water, while that at the front end is filled with oil, and also houses the circulating pump, and in this system one pump furnishes oil to the main bearing at the rear, the other to a similar member at the front, the crankshaft being a two-bearing type. Passages are drilled in the crankshaft, through which the oil goes to the lower connecting rod bearings. The oil thrown off by the rotating crankshaft is splashed to all interior parts, and lubricates the cylinders and pistons. Splash is not depended on as a drain pipe at the bottom of the crankcase allows all the oil to escape from that member. The drain pipe communicates to the bottom of the compartment partly filled with water. It is claimed that the oil which must pass through the water before it will float on its surface is not only cleaned of all foreign matter, but that it is also cooled, an important requirement in high speed motors. The oil floats on the top of the water and drips through a suitable overflow opening back into the main reservoir.

It is argued in favor of water as a filtering medium that it is not apt to get clogged up with particles of carbon as a filtering screen is. Besides, it has the added advantage of reducing the temperature of the lubricant.

Overland Model 82 Oiling System.—The oiling system (Fig. 216) is automatic and self-contained. It is of the combination force feed and splash type, in which a constant level is maintained in the oiling base. It is very simple in operation and requires

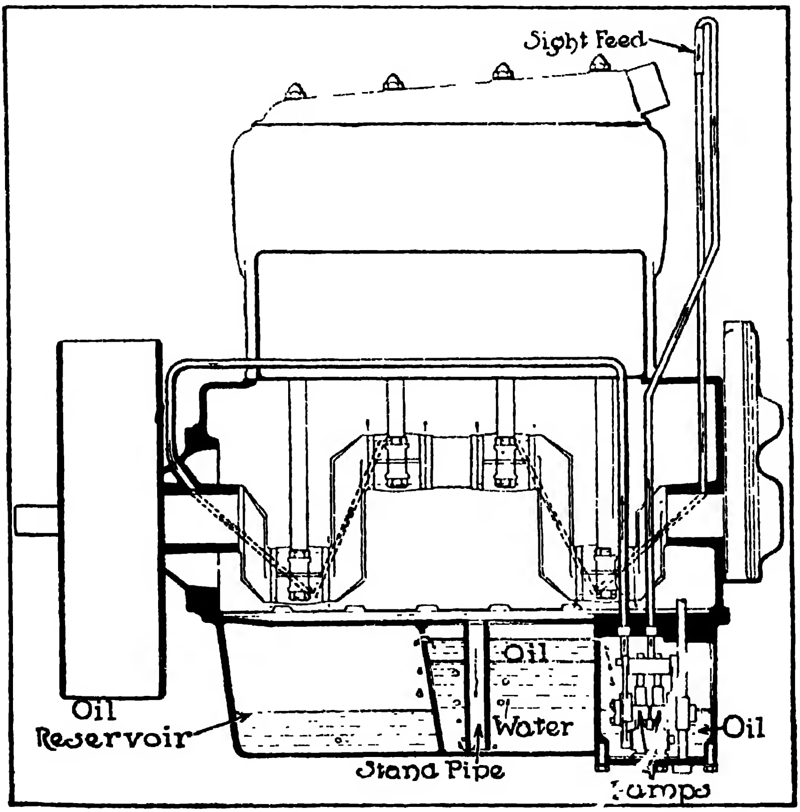


Fig. 215.—Double Pump System in Which Oil is Filtered Through Water to Remove Impurities.

no other attention than to see that the proper grade of oil is supplied through the breather pipe when the oil indicator on the left side of the crankcase indicates that oil is needed. The amount of oil necessary to make the indicator register at the word "full" is seven quarts, which is enough for from four to five hundred miles of ordinary running. The oil is circulated by a plunger

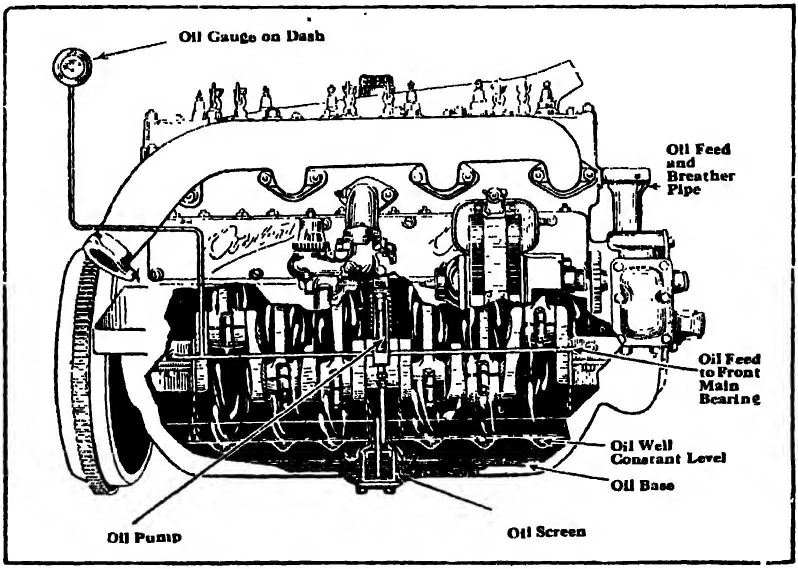


Fig. 216.—Overland Constant Level Oiling System.

pump located on the center rib of the cylinder block. The pump is operated by the camshaft.

The lubricant is drawn from the oil base through a fine mesh screen, and forced direct to the three main bearings from which it overflows to the oil pan. Six wells in the oil pan directly underneath the connecting rods are supplied with oil constantly, and a constant level is maintained at any motor speed and under all conditions of road travel. The lower end of each connecting rod is supplied with an oil dip which scoops oil directly to the connecting bearings and splashes the lubricant on the piston walls and

wrist pin bearings. The overflow from the front main bearing flows to the front timing gear. From there it is carried by gravity to all gears on the transverse shaft. It is very important that the oil strainer be kept clean so that the circulation of the oil be insured. For this reason the removal of the oil strainer has been made easy. By loosening the four stud nuts on the bottom of the crankcase the cylinder screen may be withdrawn and cleaned by dipping it in a pail of gasoline.

In replacing the screen it is well to shellac the gasket between the strainer flange and crankcase to make sure that the lubricant is properly retained. A drain plug is also provided in the bottom of the crankcase for draining the lubricant. This should be done once every thousand miles. The crankcase should then be washed out with kerosene into the breather pipe. After the kerosene has been removed replace the plug and refill the system by using the old lubricant, being careful to strain it through a fine grade of muslin, and add fresh lubricant to make up the proper amount.

The proper working of the system is indicated by a pressure gauge located upon the instrument board of the cowl dash of the car in plain view of the driver. It is not necessary that this gauge indicate a given amount of pressure in pounds; it will be sufficient to notice the slightest detection of pressure by the needle moving to the right when the motor is accelerated. For motor lubrication use a light cylinder oil, free from carbon and having a flash-point of not lower than 425, and a fire-point of not less than 475 degrees Fahrenheit.

Another forced feed system in which no reliance is placed on splash feed due to the connecting rods dipping the lubricant is shown at Fig. 217. This is used on some Pierce-Arrow six-cylinder motors, and includes a novel feature of having the oil supplied drawn from the oil container at the bottom of the crankcase to an oil reservoir carried above the cylinders. While the oil is supplied to the reservoir by the pump it flows to the bearing points indicated by gravity through oil supply tubes of large size. Both the oil reservoir and the bottom of the crankcase are inclined twenty-five degrees, this inclination being given to the oil reservoir when running up or down a grade, each lead will get an

equal supply of oil. There are eight of these leads at the bottom of the oil reservoir, one leading to the timing gear compartment of the crankcase, the others to the main bearings of the crankshaft. The connecting rods are lubricated through suitable drilled passageways in the crankshaft. As is true of other systems of this nature, the interior of the engine base is filled with an oil mist all the time that the engine is in operation, this serving to

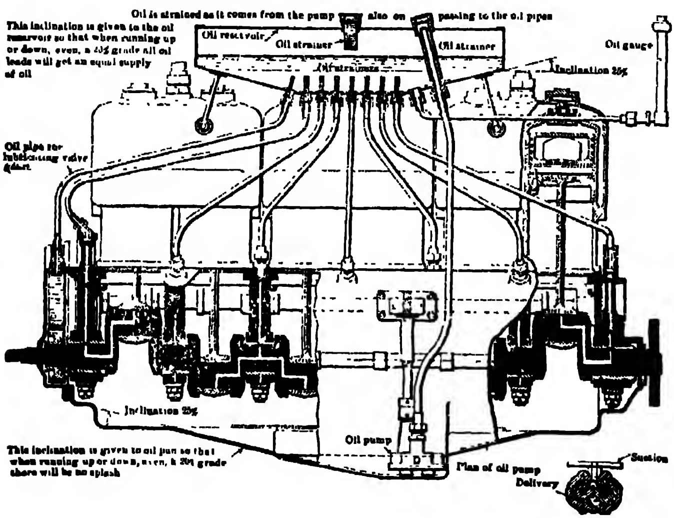


Fig. 217.—Oiling System Used on Many Early Pierce-Arrow Motors.

lubricate the piston, cylinder walls, and valve operating mechanism.

The simple pressure feed system used on the National car is shown at Fig. 218. In this the bottom of the crankcase serves as a main reservoir for the lubricant. It is drawn from this by a geared oil pump driven by bevel gearing from the camshaft, the discharge from the pump being piped to an indicator gauge on the dash. The return from this indicator is directed to a conduit running the length of the crankcase which supplies the oil to the

compartments into which the connecting rods dip to splash the lubricant about the crankcase interior. Attention is directed to the oil wells or pockets above the main bearings which catch part of the oil distributed by the connecting rods and which feed it to the main crankshaft bearings.

Another example of the system in which the oil is forced to the main bearings and from these members to the crankshaft interior which is used on the Marmon motor, is shown at Fig. 219. This operates in the same manner as the Pierce-Arrow system out-

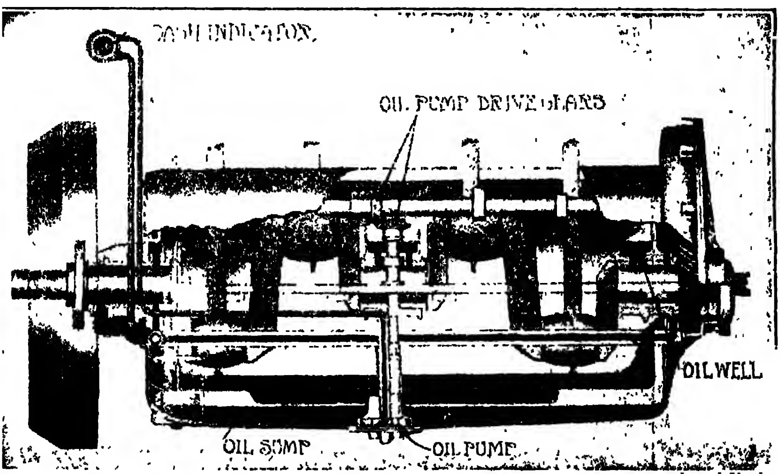


Fig. 218.—Constant Level Splash System of National Automobile.

lined at Fig. 217, except that all of the lubricant is carried in oil reservoirs attached to the bottom of the crankcase. On some engines, especially of the Knight slide valve form, it is desirable to increase the oil supply as the engine speed increases. This may be easily done, as shown at Fig. 220, by providing swinging oil troughs operated by linkage which is interlocked with the carburetor throttle actuating lever. A top view of the system showing the six oil troughs is given at A. At B the various positions of the trough for high throttle, intermediate throttle, and low throttle are clearly indicated by dotted lines. A side sectional view at C shows the supply pipes used to fill the troughs, and

also shows the rod employed to tilt the trough. With these members in the position indicated the connecting rod will take out more oil on account of the higher level. This position is used only on the highest motor speeds. On the intermediate speeds not as much oil is required as when the engine is running fast, therefore the troughs are tilted to a point where the oil level will be reduced. This system has the advantage of preventing smoking

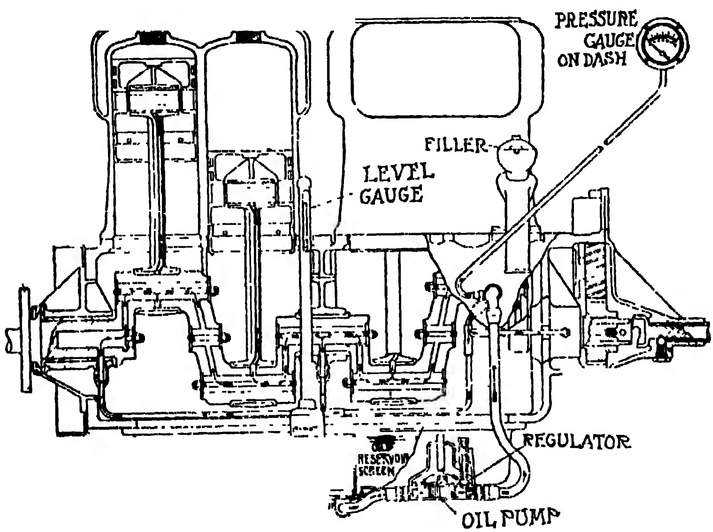


Fig. 219.—Pressure Feed Oiling System Used on Marmon Automobiles.

due to burning too much oil, as in those systems where immovable troughs are employed the level of oil in these members must be kept high enough to supply positive lubricity at high motor speeds. Obviously, this amount of lubricant may be too much for lower engine speeds and the surplus lubricant will be discharged through the exhaust in the form of smoke.

The pressure feed system used on the Cadillac eight-cylinder V motor is shown at Fig. 221. In this it will be observed that the oil is supplied to the three main bearings of the four-throw crankshaft by pipes leading from a manifold running along the oil reser-

voir, and is also directed to the camshaft bearings through a smaller manifold. The connecting rod bearings are oiled through passages drilled in the crankshaft. The oil is circulated by a gear pump driven from the crankshaft by spiral gearing, the intermediate gear serving to drive the two water pumps, one at

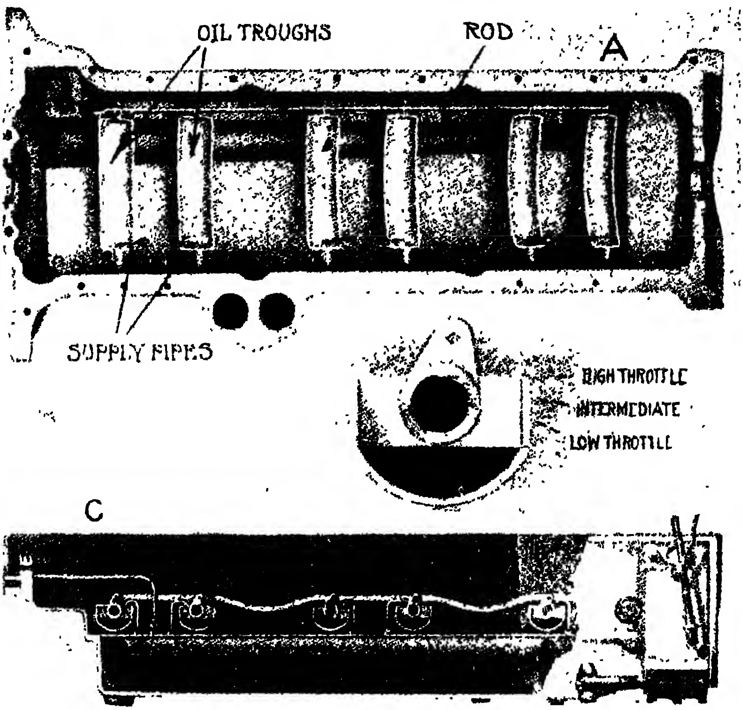


Fig. 220.—How Tilting Troughs, Regulated by the Throttle Control, Vary the Oil Supply for Different Engine Speeds.

each side of the motor, by means of a cross shaft. An adjustable by-pass valve is provided so that the oil pressure may be maintained to any desired point.

Where to Look for Trouble in Lubrication Systems.—But little trouble will be experienced with the constant level splash system in which the oil is circulated by a positive pump through

passages cored in the motor base instead of long external pipes. Considerable trouble is experienced on the old style cars having a large number of individual leads running from a mechanical oiler or compression feed oiler to the various bearing points. The simple sight feed lubricator employing compression pressure to cause the oil to circulate from the tank to the manifold fittings would indicate a clogged pipe in a positive manner as the oil drip feed glass

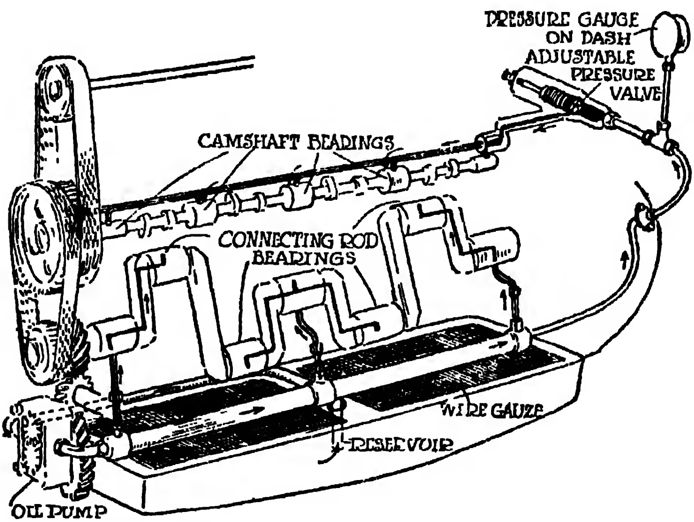


Fig. 221.—Oiling System of Cadillac 1915 Eight Cylinder Engine.

would fill up if the pipe is constricted for any reason. In event of the failure of the oil to drop in the sight feed glasses when the adjustment screws are loosened to supply more lubricant, the various pipe connections should be examined. The first one to look at is the pressure pipe running to the tank. The first essential is to make sure that the tank filler cap seats securely, and that the leather washer is interposed as packing under the cap. Disconnect the pipe next to the check valve and with the motor running note if there is any pressure, i.e., if impulses from the

exhaust can be felt on the hand. If not, the nipple of the exhaust manifold or pipe should be removed and cleaned as it may be choked with carbon, especially if considerable oil is fed to the motor. The check valve near the tank may also be fouled up, due to foreign matter. This should be taken apart and cleaned, replaced, and the engine again started for testing the pressure. A simple method of quickly locating the fault in a system of this kind is to disconnect the pressure pipe at the tank and blow through the check valve member. If the tank and oil pipe connections are tight the oil will flow through the sight feed glasses. and it will be apparent that the trouble is due to not enough pressure being supplied the tank.

Leaks may exist between the sight feed glasses and their holders, and this is usually denoted by leakage of the lubricant around the bottom of the glass. In disassembling and readjusting this member, care should be emphasized after new packing washers have been replaced. when readjusting not to screw down the fittings against the glasses too tightly as the glasses may be broken. When the glass fills up with lubricant, which is a sure indication of a clogged feed pipe, that member should be removed and thoroughly cleared by compressed air blast or steam under pressure. The steam is to be preferred as it will heat up any solidified wax or grease in the pipes. These sight feed glasses are apt to accumulate dust and dirt, especially as they are mounted in an exposed position in order to note at a glance if oil is dropping properly. A suggestion is given at Fig. 222, A, for removing dirt when the parts are difficult of access with a cloth, which is especially true when the sight feeds are assembled in a manifold fitting, as shown at B, where they are placed directly on the dash. A coarse, soft string is used, a couple of turns being made around the glass, then by imparting a sawing motion to the ends of the cord the encrusted deposit will be easily removed.

In those lubricating systems having individual leads running from a mechanical oiler, if failure of oil to reach the bearing is not due to a broken or constricted feed tube the trouble must exist at the pump supplying that member. The common fault in plunger pumps is failure of the check valves to seat properly.

this being due generally to dirt in the oil. Of course, if the main driving means fails the pumps will not move and no oil will be circulated. Oil pumps are not so apt to wear out as water pumps

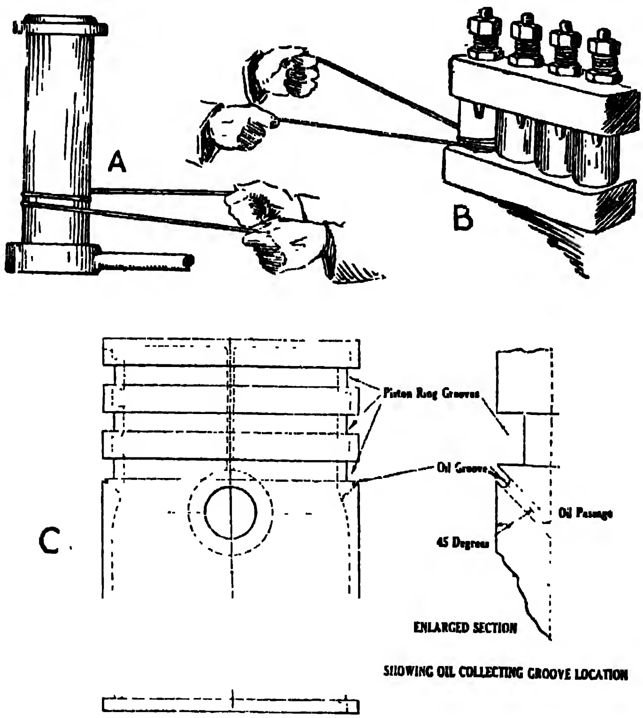


Fig. 222.—Showing Simple Method of Cleaning Sight Feed Manifold Glasses at A and B. One Method of Curing Smoky Motor shown at C.

are on account of the lubricating properties of the oil, which tends to minimize depreciation by keeping friction at a low point.

Method of Curing Smoky Motor.—The owner of a practically new car was much annoyed with a smoky exhaust which clearly indicated that oil was working by the piston rings, and that this

condition was evident even when the level of oil was below the point recommended by the makers of the car if the motor was run at high speeds. It was evident that the trouble was not due to mechanical depreciation as the car was practically new. After considerable study a cheap and successful remedy for the trouble was devised.

The cylinder head was removed, the connecting rod bearings were loosened and the four pistons, after marking each, were removed. Next the wristpins and connecting rods were taken off, and each piston, after taking out the two lowest piston rings, was chucked up in the lathe separately. A small groove, a sixteenth of an inch in diameter, was cut into the piston, as shown in Fig. 222, C, at an angle of 45 degrees. The cut started from the edge of the bottom of the next to lowest piston ring groove. This cup was also one-sixteenth of an inch in depth, thus forming a cup-shaped groove the entire circumference of the piston. Next the piston was drilled at the same angle of 45 degrees with a one-sixteenth inch drill. These holes, about one inch apart, were drilled clear through the piston. The effect of this groove was to collect the oil backed up by the bottom piston ring on the downward stroke. The small holes drained the oil into the inside of the piston and thus back to the crankcase.

The rings were replaced, the wristpins and connecting rods put back, the pistons slipped into the cylinders and the connecting rods tightened up. Next the cylinder head was replaced and oil put into the crankcase, the level of which was raised one-quarter inch above normal. When the motor was started the abnormal amount of smoke which the little engine had formerly produced failed to appear. After using his car a month, the owner called at the garage to state that the job had proved satisfactory. A repair of this kind can be made only when there is sufficient wall thickness to the piston.

Simple Oil Filter.— There are many occasions when oil is drawn from a motor crankcase or sump when it still possesses lubricating qualities, but is unsuitable for use owing to the presence of dirt. Even if an oil is unsuitable for cylinder lubrication, it may still possess sufficient lubricating value to be used around the unim-

portant bearing-points of the car to which it can be applied with a hand oil can or syringe. Instead of throwing away the oil it is possible to save quite a few gallons in the course of a year, if the simple filtering device as shown at Fig. 223 is used. This may be made up by any tinsmith at small cost. It consists of a main container of galvanized iron having a tight-fitting cover so dirt will not get into it. Three ledges are soldered to the sides of the tank as indicated, the one at the top holding a brass wire gauze screen, the two lower ones acting as supports for funnels. The discharge opening of each funnel is filled with clean waste, and by the time the oil reaches the bottom of the container it has been thoroughly filtered, the larger particles of dirt being restrained by the brass screen, while the remainder is held by the waste plugs. A petcock is soldered to the bottom of the tank, so the filtered oil may be drawn out as needed.

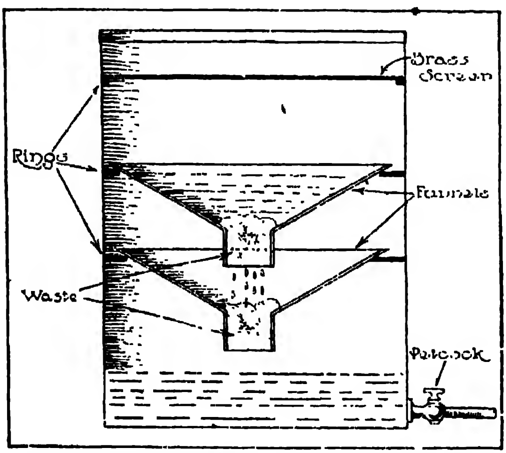


Fig. 223.—Easily Made Oil Filter for Garage Use.

Requirements of Lubricating Oils.—Much difference of opinion exists relative to the best grade of lubricating oil to use in the automobile power plant, some repairmen favoring the use of a very light, free flowing oil, others recommend oils of medium body. The best oil to use depends entirely upon the type of power plant and closeness of fit between the parts of the mechanism; no one grade of oil is suitable for all engines. The following extract from a paper read by Harry Tipper, an authority on lubricants and lubrication, before the S. A. E., outlines the points involved in the selection of a suitable lubricating medium very clearly, and may be read with profit by all motorists and repairmen.

"Inasmuch as the arbitrary tests to determine the physical characteristics of the oil do not illuminate its value for any particular purpose, let us consider what the oil should do. In order to bring this directly to the point of greatest interest to the society, that is, the lubrication of the motor of automobiles, let me suggest the requirements which a lubricant for this purpose should meet:

1. The oil should possess a sufficient body to keep the bearing surfaces apart at the temperature at which the bearings run.
2. It should possess such qualities as will reduce the friction to a minimum.
3. The flash point should be sufficiently high to insure against the presence of volatile constituents.
4. It should remain fluid at such low temperatures as will be met in service conditions.
5. It should have no tendency to decompose or to form such deposits as will gum up the machine and increase the friction, where the object is to decrease it.
6. It should contain no ingredients which will corrode or pit the metal.

"In considering the qualifications to be added to these general requirements in order to define application to the mechanical conditions of cylinder lubrication, it is necessary to consider the questions involved in the operation of an internal combustion engine, which are different from those of any other type. What I have to say now may appear very elementary from a mechanical standpoint, but unless it is mentioned, the important bearing which it has upon lubrication will not be as obvious as I want to make it. After a charge has been taken into the cylinder on the suction stroke it is compressed to from 50 to 75 pounds before being fired. Naturally upon the starting of the compression stroke there is a tendency for the gasoline mixture to leak. There are two ways of obviating this difficulty, of securing full compression. These two ways might be stated as mechanically secured compression, formed by the close fit between the piston or piston rings and the cylinder wall; or compression secured by liquid seal, which means the use of an easy clearing between the piston rings and the

cylinder wall and the sealing of the space between them by the use of a proper kind of lubricating oil. In respect to the mechanically secured compression the following points are worth noting as axioms which must be taken into consideration in estimating the conditions:

1. The closer the fit, that is, the less the clearance between the piston and cylinder walls, the more the power absorbed in turning the engine over. In fact, it is possible to secure perfect compression in this way only by securing so tight a fit that the mechanism will not turn. Even in practice good compression can be secured only at the sacrifice of some of the effective power.

2. The closer the mechanical fit between piston and cylinder walls the thinner a lubricating oil which will work its way between them. The thinner the lubricating oil the greater will be the wear and tear, because of the impossibility of keeping the metal surfaces apart where the clearances are so small and the lubricant must be such a slight film.

"With these conditions, when wear and tear has once begun, every stroke of the engine increases the loss of compression, the consumption of lubricating oil, the consumption of gasoline, in proportion to the amount of power, and, in fact, decreases continually the efficiency of the motor. You will readily see the impossibility of securing and maintaining maximum efficiency under the conditions. The motor after leaving the factory is run at great variations of speed and considerable variation of load. These variations are quite rapid and frequent. On account of the mechanical conditions of the motor you have recommended a very thin, light lubricating oil for the motor, under the guarantee. This lubricating oil has no particular adhesiveness and will flow as readily from the cylinder wall as to it. Consequently, during the rapid and frequent variations of speed, cylinder walls are sometimes overburdened with oil and sometimes practically dry, making wear and tear excessive and naturally resulting in a very rapid increase in the space between the piston and cylinder wall. This wear and tear is not thoroughly even; the clearance is larger in some places than in others. Then the lubricating oil flows freely up and down the walls of the cylinder and there is never any time

when just the proper amount of oil is on the cylinder wall. The oil is so thin that it cannot be held in the increased space, consequently on the compression stroke the gasoline mixture escapes past the piston, destroying the lubricating oil in the crankcase, and reducing from 15 to 30 per cent. the power which should be secured from the gasoline. Further, the condition under discussion is responsible largely for the carbon which is so constantly being experienced on account of the fact that the oil, being very light in body and free-flowing, is drawn up during the suction stroke into the compression chamber and onto the piston head, where it is distilled, leaving a coke baked on the piston head to the first ring, upon the valves, etc.

"Consider, instead of the mechanically secured compression used in connection with thin oil, compression which depends upon the use of lubricating oil, the clearances being larger. From the standpoint of the mechanical efficiency of any power generator, and, in fact, any moving equipment, the best fit—that is, the mechanical fit which absorbs the least amount of power due to friction in the power generator itself—is an easy sliding fit. If dependence is to be laid, however, upon the metal and not upon the lubricating oil to maintain compression, this easy sliding fit is too loose to give the compression required. If, however, it is intended to secure the compression by the liquid seal of the lubricant, then an easy sliding fit can be given to the motor, a sufficiently heavy-bodied oil used for lubricating with the result that the metal surfaces can be kept apart, the compression can be maintained so that there will be practically no change in the lubricating oil in the crankcase, and only the ordinary wear and tear on a properly lubricated surface will take place, which wear and tear is infinitely slower than the wear and tear which usually occurs under the conditions previously mentioned. In working out lubricating oils for automobile engines we are using to-day oil of 200, 300, 500 and 750 viscosity; the oil of 200 seconds viscosity being used entirely for those motors which are being made with clearances too small to permit of the oil of the proper body being used. Thousands of tests by private owners, which, while they may not be accurate, indicate the general result that in practice by the use of these

heavier oils they have secured from 10 per cent. to 20 per cent. and in some cases over 30 per cent. more power from the fuel, owing to the saving of any loss on the compression stroke. On this account they have also used less lubricating oil, due to the fact that there is no admixture of gasoline, deterioration consequently being very slow. There is also less wear and tear on the cylinders and practically no trouble from carbon."

Peculiar Cause of Overheating.—A motorist who owned a very good make of car was bothered by a particularly severe case of overheating, and was at a loss to find its true cause. The motor was thoroughly overhauled to make sure that the lubricating system was functioning properly, the interior of the waterjackets was cleared of all incrustation, the radiator replaced by one of larger capacity, the pump and water piping examined to insure that the water circulation was brisk, the exhaust valves gone over to make sure that they lifted enough to release the gases and that they opened early enough, and all important members in the transmission system were inspected to see that there was no binding or harsh action at these points that would absorb power. Despite all the precautions taken, the car continued to overheat and nothing the local repairman could do prevented the trouble. The writer was finally asked to give an opinion, and after the various remedies that had been applied ineffectually had been described in detail, it seemed that but little had been overlooked, and the case assumed that mysterious aspect that often puzzles even the most expert of repairmen.

The car was not fitted with a muffler cut-out valve and the writer noticed that the muffler seemed particularly efficient as regards silence, a barely perceptible sound being heard as the gas was discharged in the air. As the overheating was accompanied by loss of power, and as the engine had very little power even when cooled it was assumed that the overheating was due to some condition of the mixture, but varying this till it was so thin that the engine backfired through the carburetor did not improve either the power or the chronic overheating. As an experiment, the muffler was removed and the car operated with a direct exhaust. The result was a revelation, as the car not only had all the power

one could reasonably expect, but there was not the slightest sign of overheating.

It was then clearly evident that the muffler was at fault, so it was taken apart and the interior carefully examined. The design was such that it would have been a very effective silencer even in normal condition, and the fact that cars of that make had a very enviable reputation for silence kept all concerned from suspecting the muffler until nearly everything else had been tried. The principle of action was to break up the gases before they reached the air by passing them through a number of baffle plates placed at intervals in the muffler shell, these being perforated by a graduated series of holes to allow the gas to pass through. The first holes, that is, those nearest the exhaust intake opening communicating with the engine were about $3/8$ inch in diameter, but each succeeding baffle plate had smaller openings but a greater number, so that the available discharge area was practically the same in all the partition plates. In the member nearest the discharge end of the muffler the holes were normally $1/8$ inch in diameter.

The engine was fitted with a constant level splash system that insured copious lubrication and the owner had not spared the oil. The result was that accumulations of soot had filled the small holes so that they were less than half their normal diameter and the back pressure resulting from this reduction of area had caused both the lost power and overheating. The holes were drilled out to a larger size, $3/16$ inch, so they would not be so liable to fill up again, and after the muffler had been thorough v cleaned so that all soot was removed from the entire series of baffle plate openings, the component was replaced and the trouble ceased. Enlarging the holes produced a little freer discharge and the car was just a trifle more noisy than it had been prior to the time the holes clogged up and caused defective engine action. Enlarging the openings was advisable, however, as they were not so liable to clog up.

CHAPTER V

LOCATION AND REMEDY OF IGNITION FAULTS

Battery Ignition System Parts—Care and Wiring of Dry Cells—Storage Battery Defects—Storage Battery Charging and Maintenance—Ignition Timers—Spark Plugs—Induction Coil Faults—Adjusting Coil Vibrators—Low Tension Ignition System—Magnetic Spark Plug System—Wiring Troubles and Electrostatic Effects—Magneto Forms—Troubles with High Tension Magneto—Contact Breaker, Care and Adjustment—Recharging Weak Magnets—Transformer Coil Magneto System—Dual Magneto System—Master Vibrator Ignition Systems—Double and Triple Ignition Methods—Two Spark Ignition—Timing Battery Ignition Systems—Timing High Tension Magnetos—Firing Orders of Typical Engines.

THERE has been no part of the automobile that has been changed more often than the ignition system. The first cars had simple battery and coil ignition, then with the introduction of the high tension magneto the systems were usually combined on the same engine in order to secure double ignition systems, either one being independent of the other. Later, as the magneto became refined and improved, a number of makers discarded the battery ignition system and placed their entire reliance on the magneto. With the coming of the demand for electrical motor starting and lighting systems came a revival of the battery ignition method which had been discarded for the high tension magneto. The main reason for using the magneto in preference to the battery system was that ignition became weaker with the latter after the engine had been run for a time owing to a lessened output of the battery. The magneto which generates electricity by a mechanical process had the advantage because the faster it was driven the more current it delivered.

In the modern automobiles an electrical current generator is provided, run by the engine which is depended on to charge a

storage battery while the motor is running, the current for ignition and lighting being taken from the storage battery instead of directly from the generator which delivers a current of varying output depending upon the engine speed which in turn regulates the rate of generator armature rotation. On many cars therefore, the battery ignition systems are used as the use of the generator keeps the battery charged always to the proper point for securing energetic ignition. The automobile repairman will have cars to repair that will use a wide variety of ignition systems, as many of those fitted with the simple battery and coil are still in use while a very large number are equipped solely with the high tension magneto. Most of the newer cars will use improved battery ignition systems with the high tension magneto eliminated.

Battery Ignition System Parts.—A battery ignition system in its simplest form consists of a current producer, usually a set of dry cells or a storage battery, an induction coil to transform the low tension current to one having sufficient strength to jump the air gap at the spark plug, an igniter member placed in the combustion chamber and a timer or mechanical switch operated by the engine so that the circuit will be closed only when it is desired to have a spark take place in the cylinders. Battery ignition systems may be of two forms, those in which the battery current is stepped up or intensified to enable it to jump an air gap between the points of the spark plug, these being called "high tension" systems and the low tension form in which the battery current is not intensified to a great degree and a spark produced in the cylinder by the action of a mechanical circuit breaker in the combustion chamber. The low tension system is the simplest electrically but the more complex mechanically. The high tension system has the fewest moving parts but numerous electrical devices. At the present time practically all automobiles use high tension ignition systems, but as the repairman may have occasion to overhaul an "old timer" instructions are given for repairing the low tension ignition systems as well as the more popular forms. Low tension ignition methods are still used in marine engines, so a mechanic working on these types as well as automobiles should familiarize himself with the principles of both high and low tension ignition systems.

Ignition troubles are usually evidenced by irregular engine action. The motor will not run regularly nor will the explosions follow in even sequence. There may be one cylinder of a multiple cylinder motor that will not function at all, in which case the trouble is purely local, whereas if all the cylinders run irregularly there is some main condition outside of the engine itself that is causing the trouble. As complete instructions are given at the end of this chapter for a systematic search to locate troubles and as these may be readily identified by the symptoms described, it is not necessary to dwell on this point any longer, at the present time. In a battery ignition system the first point to be suspected in event of irregular ignition is lack of capacity in the current producer.

Care and Wiring of Dry Cells.—The simplest form of current producer is the dry cell which is shown in section at Fig. 224, A. A zinc can about 6 inches high and 2½ inches in diameter forms the negative element of the dry cell and also serves as a container for the electrolyte and positive element. A carbon rod placed in the center is insulated from contact with the zinc can by a seal of pitch which is a non-conductor of electricity and which also serves to retain the moisture in the cell. This carbon rod does not extend entirely to the bottom of the cup. The exciting fluid or electrolyte is a solution of sal ammoniac which is held against the negative element by blotting paper which is used as a lining for the zinc can. The space between this active lining and the carbon rod is filled with a depolarizing agent, usually black oxide of manganese, which is mixed with powdered gas retort carbon, the whole being saturated with exciting fluid in order to increase the electrical conductivity of the depolarizing mixture and also to keep the blotting paper lining properly moist. The depolarizor is necessary to enable the cell to be used continuously as it gives off oxygen to combine with the electrolyte after it has given up its chlorine to the zinc which leaves hydrogen to combine with the oxygen and form water. It will be observed that a dry cell is very simple in construction and that nothing is apt to occur that will reduce its capacity except diminution in the strength of the electrolyte or eating away of the zinc can by chemical action. The

elements in a dry cell are usually combined in such proportions that about the time the electrolyte is exhausted, the zinc can will also have outlived its usefulness. It is much cheaper to replace dry cells with new ones than to attempt to repair the exhausted ones.

Evaporation of the electrolyte is the main cause of deterioration of dry cells as the internal resistance of the cell increases when

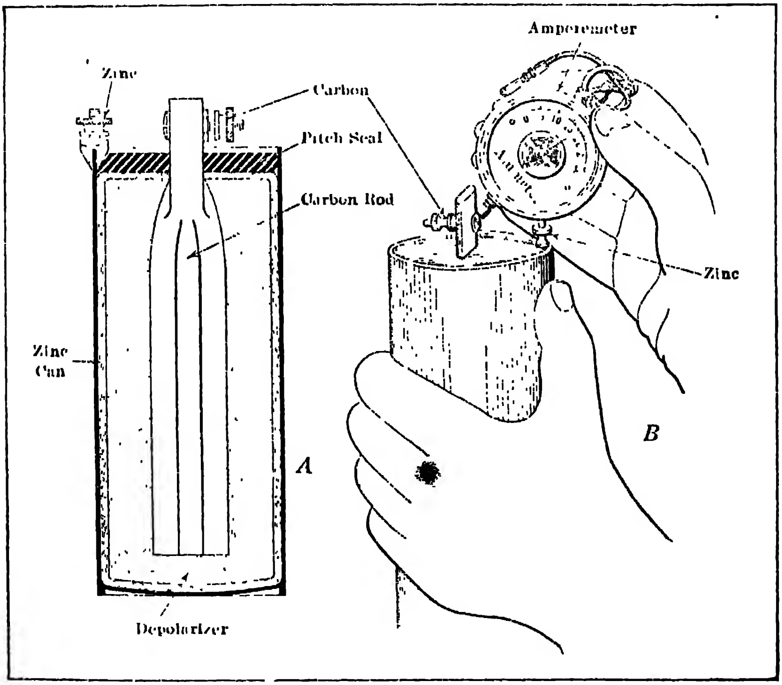


Fig. 224.—View at A, Showing Internal Construction of Dry Cell Battery. B.—Method of Testing Dry Cell with Amperemeter.

the moisture evaporates. It is said that dry cells will depreciate even when not in use, so it is important for the repairman to buy these only as needed and not to keep a large stock on hand. In order to test the capacity of a dry cell an amperemeter is used as indicated at Fig. 224, B. Amperemeters are made in a variety

of forms, some being combined with volt meters, as shown at Fig. 226. The combination instrument is the best form for the repairman to use as the volts scale can be employed for testing storage batteries while the amperemeter scale may be utilized in determining the strength of dry cells. A fully charged, fresh dry cell should show a current output of from twenty to twenty-five amperes. If the cell indicates below six or seven amperes, it should be discarded as it is apt to be exhausted to such a point that it will not furnish current enough to insure energetic or reliable ignition. Dry cells should always be stored in a cool and dry place, so that the electrolyte will not evaporate. If moisture is given an opportunity to collect on the top of the pitch seal it will allow a gradual loss of current due to short circuiting the cells. In applying an amperemeter, care should be taken to always connect the positive terminal marked with a plus sign against the carbon terminal. In the indicating meter shown at B, it is necessary to use only one contact point which is pressed against the screw passing through the carbon rod. The case of the instrument is placed in contact with the zinc terminal to complete the circuit. A flexible wire is usually included in order to test the amperage of a group of cells should this be thought necessary. When dry cells are used for automobile ignition, they should be carefully packed in a box made of non-conducting material, such as wood, and securely covered so that there will be no chance for water to enter the container. If placed in a sheet metal case, care should be taken to line the box with insulating material and also to pack the cells tightly so they cannot shake around. The best practice is to use wedges or blocks of wood which are driven in between the cells to keep them apart. In no case should a dry cell be placed directly in a steel box, as the binding posts on the zincs might come in contact with the walls of the box and tend to short circuit the cells, producing rapid depreciation. A battery box should always be placed at a point where it is not apt to be drenched with water when the car is washed or should be watertight if exposed.

When dry cells are used for ignition there are two practical methods of connecting these up. At least four dry cells are neces-

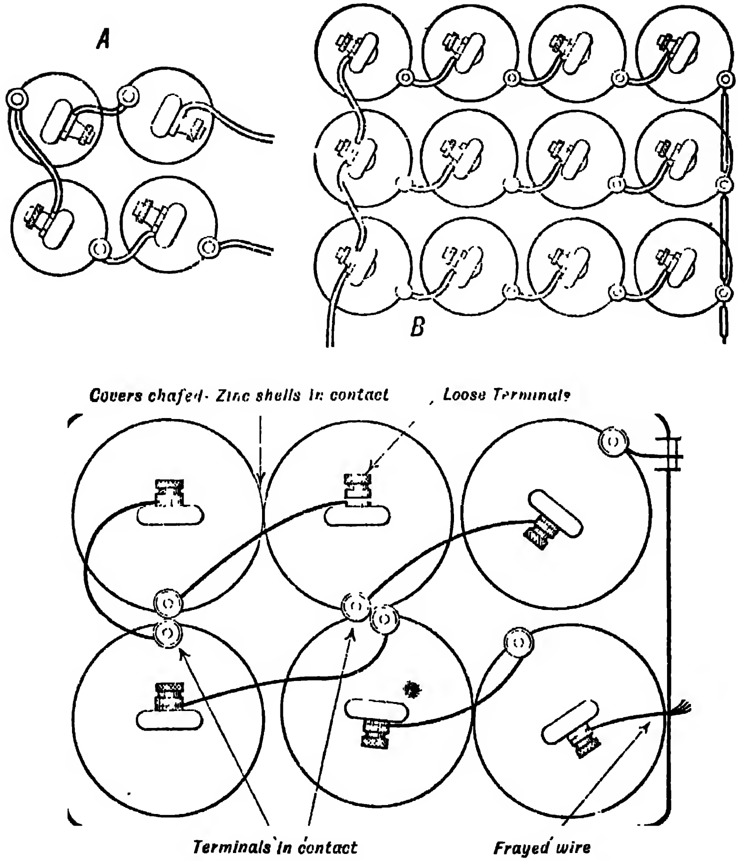


Fig. 225.—Methods of Connecting Dry Cells and Precautions to be Observed When Wiring.

sary to secure satisfactory ignition and much more energetic explosions will be obtained if five or six are used. The common method is to join the cells together in series as shown at Fig. 225, A. When connecting in this manner the carbon terminal of one battery is always coupled to the zinc binding post of its neighbor. Connection would be made from the carbon of the first

cell to the zinc of the second, from the carbon of the second to the zinc of the third, and from the carbon of the third to the zinc of the fourth, this leaving the zinc terminal on the first cell and the carbon terminal on the fourth cell free to be joined to the external circuit. When dry cells are connected in series the voltage is augmented, that of one cell being multiplied by the number so joined. The amperage remains the same as that of one cell. If a dry cell has a potential of 1¼ volts, a battery composed of four cells would show 5 volts. When dry batteries are used for lighting purposes or for igniting multiple cylinder engines, in order to obtain better results, they are connected in series multiple, as shown at B. Three sets of cells joined in series are placed side by side with the free carbons at one end in line and the zincs at the other also in line. The three carbons are then joined together by one wire, the three zinc terminals by another. When joined in this manner the battery has a voltage equal to that of four cells and an amperage equal to that of three cells. If a series connected battery as at A, indicates 5 volts and 20 amperes, the series multiple connection at B will indicate 5 volts and 60 amperes. When cells are joined in multiple the drain on any one cell is reduced and it is not so likely to become exhausted as when four are used in series. The points to be watched out for when installing dry batteries are clearly outlined at the bottom of Fig. 225. It will be seen that it is not desirable for terminals to come in contact with each other or with the sides of the box nor is it conducive to good ignition to have the zinc shells in contact. A loose terminal on any one of the batteries will result in irregular ignition while a broken wire will interrupt it altogether. If the insulation is frayed where a wire passes through a hole in a metal battery box trouble may be experienced due to short circuiting of the current between the bare wire and the steel box, which may be grounded.

Storage Battery Defects.—The subject of storage battery maintenance was thoroughly covered in a paper read by H. M. Beck before the S. A. E. and published in the transactions of the society. Some extracts from this are reproduced in connection with notes made by the writer and with excerpts from ins-

struction books of battery manufacturers in order to enable the reader to secure a thorough grasp of this important subject without consulting a mass of literature. Endeavor has been made to simplify the technical points involved and to make the exposition as brief as possible without slighting any essential points. In view of the general adoption of motor starting and lighting systems on all modern automobiles, the repairman or motorist must

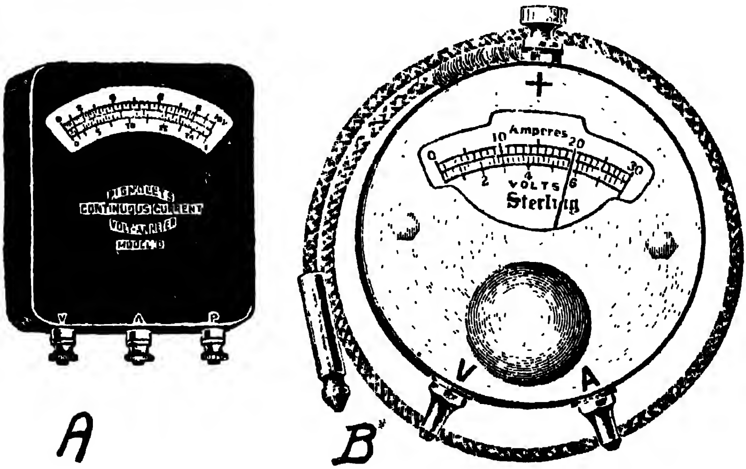


Fig. 226.—Two Forms of Combination Volt-Amperemeters for Garage Service.

pay more attention to the electrical apparatus than formerly needed when the simple magneto ignition system was the only electrical part of the automobile. The storage battery is one of the most important parts of the modern electrical systems and all up-to-date repairmen must understand its maintenance and charging in order to care for cars of recent manufacture intelligently.

A storage battery, from an elementary standpoint, consists of two or more plates, positive and negative, insulated from each other and submerged in a jar of dilute sulphuric acid. The plates

consist of finely divided lead, known as the active material, held in grids which serve both as supports and as conductors for the active material. The active material being finely divided, offers an enormous surface to the electrolyte and thus electro-chemical action can take place easily and quickly. Two plates such as described, would have no potential difference, the active material of each being the same. If, however, current from an outside source is passed between them, one, the positive, will become oxidized, while the other remains as before, pure lead. This combination will be found to have a potential difference of about two volts, and if connected through an external circuit, current will flow.

During discharge, the oxidized plate loses its oxygen and both plates will become sulphated until, if the discharge is carried far enough, both plates will again become chemically alike, the active material consisting of lead sulphate. On again charging, the sulphate is driven out of both plates and the positive plate oxidized and this cycle can be repeated as often as desired until the plates are worn out. Thus charging and discharging simply result in a chemical change in the active material and electrolyte, and the potential difference between the plates and capacity is due to this change.

In taking care of a storage battery, there are four points which are of the first importance:

First—The battery must be charged properly.

Second—The battery must not be overdischarged.

Third—Short circuits between the plates or from sediment under them, must be prevented.

Fourth—The plates must be kept covered with electrolyte and only water of the proper purity used for replacing evaporation.

In the event of electrical trouble which may be ascribed to weak source of current, first test the battery, using a low reading voltmeter. Small pocket voltmeters can be purchased for a few dollars and will be found a great convenience. Cells may be tested individually and as a battery. The proper time to take a reading of a storage battery is immediately upon stopping or while the engine is running. A more definite determination can be made than after the battery has been idle for a few hours and

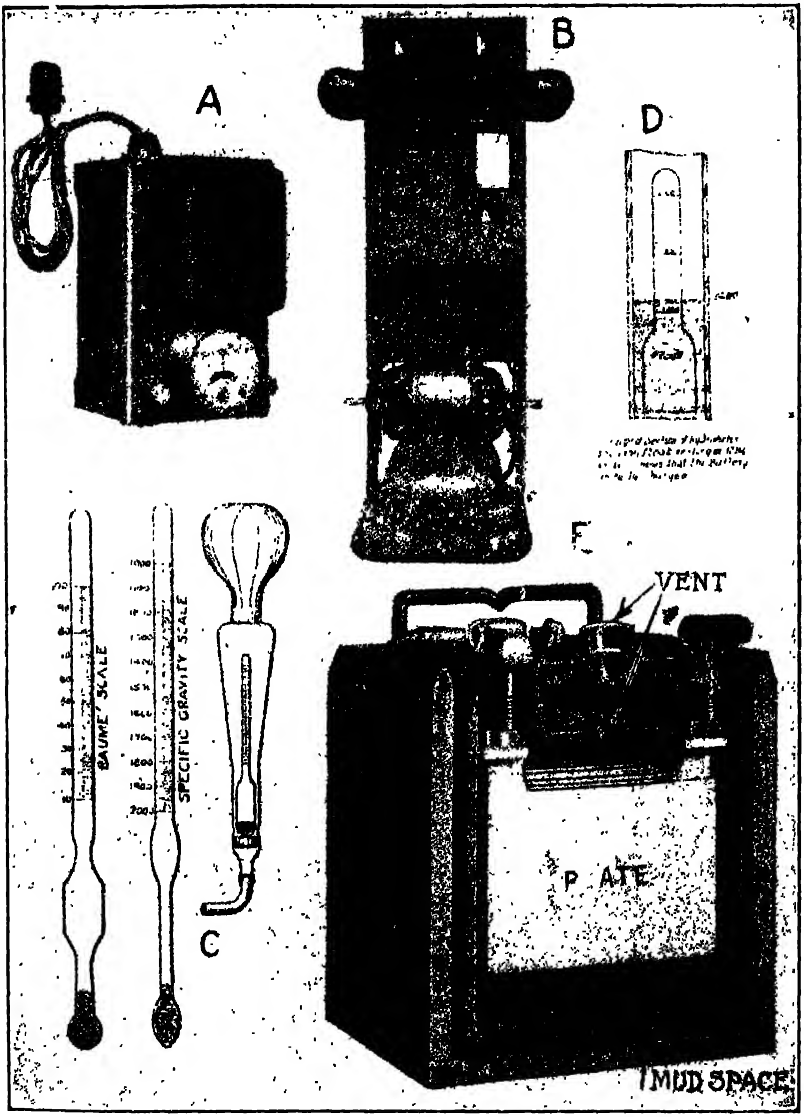


Fig. 227.—Devices Used in Charging and Caring for Storage Batteries.

has recuperated more or less. A single cell should register more than two volts when fully charged, and the approximate energy of a three-cell battery should be about 6.5 volts. If the voltage is below this the batteries should be recharged and the specific gravity of the electrolyte brought up to the required point. If the liquid is very low in the cell new electrolyte should be added. To make this fluid add about one part of chemically pure sulphuric acid to about four parts of distilled water, and add more water or acid to obtain the required specific gravity, which is determined by a hydrometer. According to some authorities the hydrometer test should show the specific gravity of the electrolyte as about 1.208 or 25 degrees Baume when first prepared for introduction in the cell, and about 1.306 or 34 degrees Baumé when the cell is charged.

The following table gives the corresponding specific gravities and Baumé degrees:

Baumé	Specific Gravity	Baumé	Specific Gravity
0	1.000	18	1.141
1	1.006	19	1.150
2	1.014	20	1.160
3	1.021	21	1.169
4	1.028	22	1.178
5	1.035	23	1.188
6	1.043	24	1.198
7	1.050	25	1.208
8	1.058	26	1.218
9	1.066	27	1.228
10	1.074	28	1.239
11	1.082	29	1.250
12	1.090	30	1.260
13	1.098	31	1.271
14	1.106	32	1.283
15	1.115	33	1.294
16	1.124	34	1.306
17	1.132	35	1.318

The appended conversion formula and table of equivalents will be found of value in changing the reading of a hydrometer,

or acidometer, from terms of specific gravity to the Baumé scale or vice versa.

$$\text{Sp. Gr.} = \frac{145}{145 - \text{Baumé degrees}} \text{ at } 60° \text{ F.}$$

Either voltage or gravity readings alone could be used, but as both have advantages in certain cases, and disadvantages in others, it is advisable to use each for the purpose for which it is best fitted, the one serving as a check on the other. Voltage has the great disadvantage in that it is dependent upon the rate of current flowing. Open circuit readings are of no value, as a cell reads almost the same discharged as it does charged. On the other hand, a voltmeter is a very easy instrument to read and may be located wherever desirable. Specific gravity readings are almost independent of the current flowing, but the hydrometer is difficult to read, not very sensitive and the readings must be taken directly at the cells.

Charging the Storage Battery.—Great care should be used in charging and the charging rates given by the various manufacturers should be followed whenever possible. It is essential that the positive wire carrying the charging current be connected with the positive plates of the battery. The positive pole of a cell is usually indicated by a plus sign or by the letter "P." In case of doubt always ascertain the proper polarity of the terminals before charging. This is done by immersing the ends in acidulated water, about an inch apart. The one around which the more bubbles collect is the negative, and should be connected with negative pole of the battery. If a cell is not connected properly it will be ruined. A battery always should be charged, if possible, at a low charging rate, because it will overheat if energized too rapidly. The normal temperature is between 70 and 90 degrees Fahrenheit. When the battery is fully charged the solution assumes a milky white appearance and bubbles of gas are seen rising to the surface of the electrolyte. All foreign matter should be kept out of the batteries as any metallic substance finding its way into the cell or between the terminals will short circuit the cell and perhaps ruin it before its presence is known. The

terminals, the outside of the cell and all connections, should be kept free from acid or moisture. A neglect of these essentials means corrosion and loss of capacity by leakage. There is one point in connection with the charge which should be especially emphasized, namely, that the final voltage corresponding to a full charge is not a fixed figure, but varies widely, depending upon the charging rate, the temperature, the strength of the electrolyte, and age of the battery. For this reason, charging to a fixed voltage is unreliable and likely to result disastrously. The charge should be continued until the voltage or gravity cease rising, no matter what actual figures are reached. Old cells at high temperatures may not go above 2.4 volts per cell, whereas if very cold, they have been known to run up to three volts.

The points to be especially emphasized in connection with the charge are:

First—On regular charges keep the rates as low as practical and cut off the current promptly. It is preferable to cut off a little too soon rather than to run too long where there is any question.

Second—Overcharges must be given at stated intervals and continued to a complete maximum. They should be cut off at the proper point, but when in doubt it is safer to run too long, rather than to cut off too soon.

Third—Do not limit the charge by fixed voltage.

Fourth—Keep the temperature within safe limits.

Fifth—Keep naked flames away from cells while charging as the gas given off is inflammable. Always see that gas vents are clear before charging.

The following table will undoubtedly be of value as a guide to the proper charging rates of batteries of various ampere hour capacities, the assumption being that these are all 3 cell batteries that will show between 6.5 and 7.5 volts when fully charged. While most manufacturers of batteries furnish instruction books, these may be lost, so some compact reference is needed. The overall dimensions of the batteries are given so the capacity may be determined even if the marks of identification on the name plate are obliterated.

TABLE OF CHARGING RATES

Elba Lighting Batteries

Type.	Normal Charging Rates. Amp. Required.		24-Hr. Charging Rate	Volts per Cell at End of Charge at 24-Hr. Rate	Volts of Battery at End of Charge at 24-Hr. Rate	Size of Battery Over all			No. of Cells
	Start	Finish				Length in in.	Width in in.	Height in in.	
ELB—60-90.......	9	3	3	2½	½	10⅜	7½	9½	3
ELB—80-120......	12	4	4	2½	7½	11½	7½	9½	3
ELB—100-150.....	15	5	5	2½	7½	12⅞	7½	9½	3
ELB—120-180.....	18	6	6	2½	7½	15⅜	7½	9½	3
HSB—60-90.......	9	3	3	2½	7½	9¾	6	10	3
HSB—80-120......	12	4	4	2½	7½	11	6	10¾	3
HSB—100-150.....	15	5	5	2½	7½	12⅜	6	10¾	3
HSB—120-180.....	18	6	6	2½	7½	15	6	10¾	3
PAB—120-180.....	18	6	6	2½	7½	10⅛	7½	14¼	3

A battery may be charged from any source of direct current. Garages, central stations, lighting plants, etc., can do the work, and in many instances where direct current is used for power purposes, a simple charging outfit is operated from the dynamo. Where alternating current only is available, a rectifier which changes alternating current to direct current may be installed and the battery charged with no inconvenience and at comparatively small cost. All of these methods will be considered in proper sequence and typical charging outfits described.

Remedies for Loss of Battery Capacity.—When a battery gives indication of lessened capacity it should be taken apart and the trouble located. If the cell is full of electrolyte it may be of too low specific gravity. The plates may be sulphated, due to lack of proper charge or too long discharge. The cells may need cleaning, a condition indicated by short capacity and a tendency to overheat when charging. Sometimes a deposit of sediment on

the bottom of the cell will short circuit the plates. If the specific gravity is low and the plates have a whitish appearance, there being little sediment in the cells, it is safe to assume that the plates are sulphated. Sediment should be removed from the cells and the plates rinsed in rain or distilled water to remove particles of dirt or other adhering matter.

The rate at which the sediment collects, depends largely upon the way a battery is handled and it is, therefore, necessary to determine this rate for each individual case. A cell should be cut out after say fifty charges, the depth of sediment measured and the rate so obtained, used to determine the time when the battery will need cleaning. As there is apt to be some variation in the amount of sediment in different cells, and as the sediment is thrown down more rapidly during the latter part of a period than at the beginning, it is always advisable to allow at least one-fourth inch clearance. If the ribs in the bottom of the jars are 1¾ inches high, figure on cleaning when the sediment reaches a depth of 1½ inches. Before dismantling a battery for "washing," if practical, have it fully charged. Otherwise, if the plates are badly sulphated, they are likely to throw down considerable sediment on the charge after the cleaning is completed.

There have been many complaints of lack of capacity from batteries after washing. Almost without exception this is found to be due to lack of a complete charge following the cleaning. The plates are frequently in a sulphated condition when dismantled and in any case are exposed to the air during the cleaning process, and thus lose more or less of their charge. When re-assembled, they consequently need a very complete charge, and in some cases the equivalent of the initial charge, and unless this charge is given, the cells will not show capacity and will soon give trouble again. This charge should be as complete as that described elsewhere in connection with the initial charge.

"Flushing" or replacing evaporation in cells with electrolyte instead of water, is a most common mistake. The plates of a storage battery must always be kept covered with electrolyte, but the evaporation must be replaced with pure water only. There seems to be a more or less general tendency to confuse the elec-

trolyte of a storage battery with that of a primary cell. The latter becomes weakened as the cell discharges and eventually requires renewal. With the storage battery, however, this is not the case, at least to anything like the same degree, and unless acid is actually lost through slopping or a broken jar, it should not

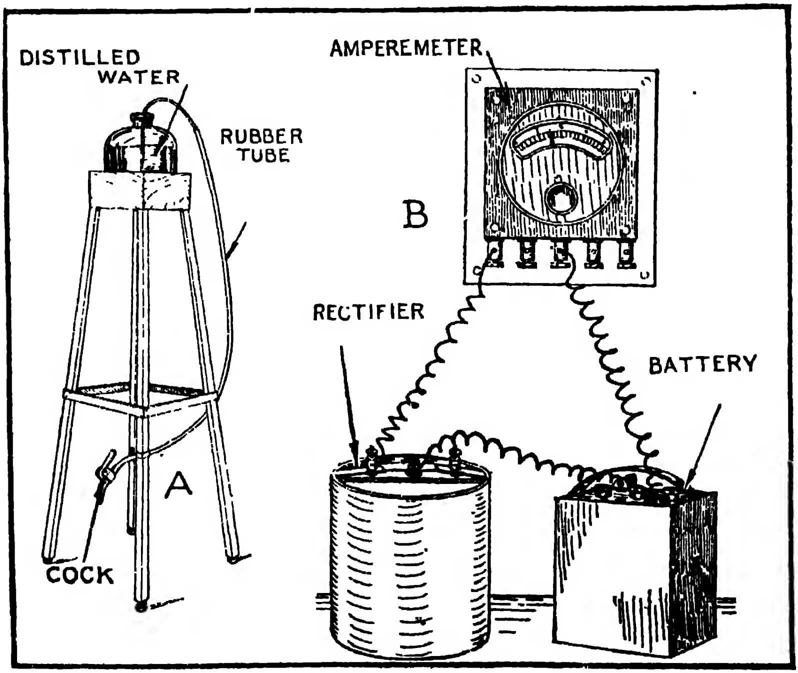


Fig. 228.—Simple Stand for Carrying Electrolyte or Distilled Water at A. Method of Using Rollinson Rectifier Shown at B.

be necessary to add anything but water to the cells between cleanings. Acid goes into the plates during discharge, but with proper charging it will all be driven out again so that there will be practically no loss in the specific gravity readings, or at least one so slight that it does not require adjustment between cleanings. Thus, unless some of the electrolyte has actually been lost, if the specific gravity readings are low, it is an indication that something is wrong, but the trouble is not that the readings are low,

but that something is causing them to be low, and the proper thing to do is to remove the cause and not try to cover it up by doctoring the indicator. The acid is in the cells and if it does not show in the readings, it must be in the form of sulphate, and the proper thing to do is to remove the cause of the sulphation if there is one, and then with proper charging, drive the acid out of the plates and the specific gravity readings will then come back to the proper point. The too-frequent practice in such cases is to add electrolyte to the cells in order to bring up the readings, which as already explained, are only the indication of the trouble, and this further aggravates the condition, until finally the plates become so sulphated that lack of capacity causes a complaint. This practice of adding electrolyte to cells instead of water, seems to be coming more and more common.

If there is any doubt about the polarity of the plates when reassembling after cleaning it is well to note that the positive plate is chocolate in color and the negative is gray.

When plates are sulphated, to restore them to their original condition it is necessary that the battery be given a long, slow charge at about a quarter or a third of the normal charging rate. This should be continued until the electrolyte has reached the proper specific gravity and the voltage has attained its maximum.

It should be understood that sulphating is a normal as well as an abnormal process in the charge and discharge of storage batteries, and the difference is in the degree, not the process. The abnormal condition is that ordinarily referred to by the term. In normal service sulphating does not reach the point where it is difficult to reduce, but if carried too far, the condition becomes so complete that it is difficult to reduce, and injury results. A very crude method of illustrating the different degrees of sulphating is to consider it as beginning in individual particles uniformly distributed throughout the active material. Each particle of sulphate is then entirely surrounded by active material. The sulphate itself is a non-conductor, but being surrounded by active material, the current can reach it from all sides and it is easily reduced. This is normal sulphate. As the action goes further the particles of sulphate become larger and join together and their outside con-

ducting surface is greatly reduced in comparison with their volume so that it becomes increasingly difficult to reduce them and we have abnormal sulphate.

The general cure for sulphating is charging, so that a cell having been mechanically restored, the electrical restoration consists simply in the proper charging. Sulphate reduces slowly and on this account it is a good plan to use a rather low current rate. High rates cause excessive gassing, heating and do not hasten the process appreciably, so that it is the safer as well as the more efficient plan to go slowly. A good rate is about one-fifth normal. The length of charge will depend upon the degree of sulphating. In one actual case it required three months' charging night and day to complete the operation, but this was, of course, an exceptional one. The aim should be to continue until careful voltage and gravity readings show no further increase for at least ten hours and an absolute maximum has been reached. In serious cases it may be advisable to even exceed this time in order to make absolutely sure that all sulphate is reduced, and where there is any question it is much safer to charge too long, rather than to risk cutting off too soon. A partial charge is only a temporary expedient, the cell still being sulphated will drop behind again.

Battery Charging Apparatus.—The apparatus to be used in charging a storage battery depends upon the voltage and character of the current available for that purpose. Where direct current can be obtained the apparatus needed is very simple, consisting merely of some form of resistance device to regulate the amperage of the current allowed to flow through the battery. The internal resistance of a storage battery is very low and if it were coupled directly into a circuit without the interposition of additional resistance an excessive amount of current would flow through the battery and injure the plates. When an alternating current is used it is necessary to change this to a uni-directional flow before it can be passed through the battery. Alternating current is that which flows first in one direction and immediately afterward in the reverse direction. When used in charging storage batteries some form of rectifier is essential. The rectifier may be a simple form as shown at Fig. 227, A, which is intended to be coupled di-

rectly into a lighting circuit by screwing the plug attached to the flexible cord in the lamp socket. A rotary converter set such as shown at B, may also be used, in this the alternating current is depended on to run an electric motor which drives the armature of a direct current dynamo. The current to charge the battery is taken from the dynamo, as it is suitable for the purpose, whereas that flowing through the motor cannot be used directly.

The view at Fig. 227, C, shows a usual form of hydrometer-syringe which is introduced into the vent hole of the storage battery such as shown at E and enough electrolyte drawn out of the cell to determine its specific gravity. This is shown on the hydrometer scale as indicated in the enlarged section at D. A very useful appliance where considerable storage battery work is done is shown at Fig. 228, A. This is a stand of simple form designed to carry a carboy containing either acid, distilled water, or electrolyte. In fact, it might be desirable to have three of these stands, which are inexpensive, one for each of the liquids mentioned. In many repair shops the replenishing of storage batteries is done in a wasteful manner as the liquid is carried around in a bottle or old water pitcher and poured from that container into the battery, often without the use of a funnel. The chances of spilling are, of course, greater than if the liquids were carefully handled and more time than necessary is consumed in doing the work. The stand shown is about 5 feet high and is fitted with castors so it may be easily moved about the shop if necessary. For example, in taking care of electric vehicle batteries it may be easier to move the carboy to the battery than to remove the heavy battery from the automobile. The container for the liquid is placed on top of the stand and the liquid is conveyed from it by a rubber tube. The rubber tube is attached to a glass tube extending down nearly to the bottom of the liquid. At the bottom of the rubber tube an ordinary chemist's clip which controls the flow of liquid is placed. In order to start a flow of liquid it is necessary to blow into a bent glass vent tube which is also inserted into the stopper. Once the rubber tube has become filled with liquid merely opening the clip will allow the liquid to flow into the battery as desired.

In most communities the incandescent lighting circuit is used

for charging batteries on account of the voltage of the power circuits being too high. The incandescent lighting circuit may be any one of six forms. A direct current of either 110 or 220 volts used over short distances, either 220 or 440 volts on three wire circuits over long distances, alternating current at a constant potential, usually 110 volts and in various polyphase systems. It might be stated that in the majority of instances house and garage lighting circuits furnish direct current of 110 volts. We will consider the devices used with the alternating form one of which is shown at Fig. 228, B. This is known as the Rollinson electrolytic rectifier which is based upon the following principles: When an element of aluminum and a corresponding element or plate of iron are submerged in a solution of certain salts, using these elements as negative and positive terminals, respectively, the passage of an electric current through the solution produces a chemical action which forms hydroxide of aluminum. A film of hydroxide thus formed on the aluminum element repels the current. The arrangement of the cell will then permit current to pass through it in one direction only, the film of chemical preventing it from passing in the opposite direction. The result is that if an alternating current is supplied to the cell a direct pulsating current can be obtained from it. The outfits usually include a transformer for reducing the line voltage to the lower voltages needed for battery charging purposes. Regulation of the current is effected in the simplest type by immersing the elements more or less in the solution in the jar. As complete instructions are furnished by the manufacturers it will not be necessary to consider this form of rectifier in detail.

One of the most commonly used rectifying means is the mercury arc bulb. This device is a large glass tube of peculiar shape, as shown at Fig. 229, which contains in the base a quantity of mercury. On either side of this lower portion two arms of the glass bulbs extend outwardly, these being formed at their extremities into graphite terminals or anodes indicated as A and A-1. The current from the auto transformer is then attached one to each side. The base forms the cathode or mercury terminal for the negative wires. The theory of this action is somewhat complicated,

but may be explained simply without going too much into detail. The interior of the tube is in a condition of partial vacuum and while the mercury is in a state of excitation a vapor is supplied. This condition can be kept up only as long as there is a current flowing toward the negative. If the direction of the current be

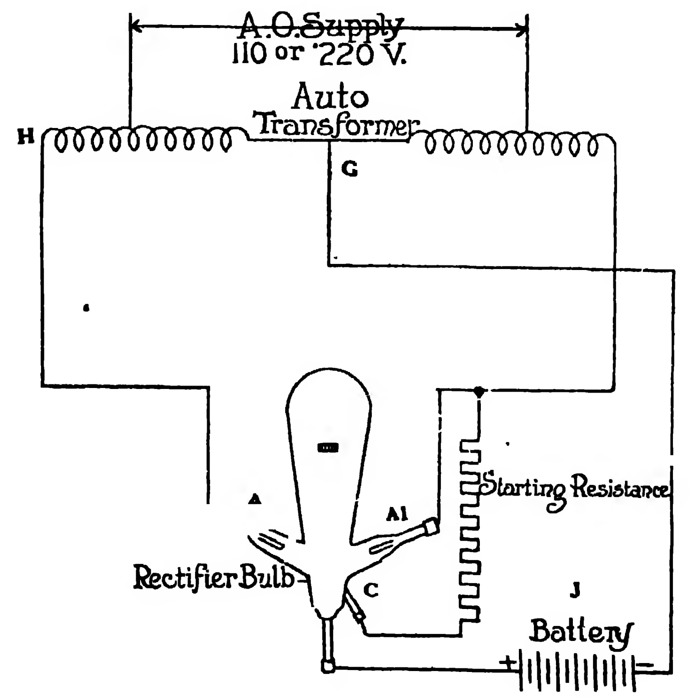


Fig. 229.—Wiring Diagram Defining Use of Mercury Arc Rectifier.

reversed so that the formerly negative pole becomes a positive the current ceases to flow, as in order to pass in the opposite direction it would require the formation of a new cathode element. Therefore the flow is always toward one electrode which is kept excited by it. A tube of this nature would cease to operate on alternating current voltage after half a cycle if some means were

not provided to maintain a flow continuously toward the negative electrode. In the General Electric rectifier tube there are two anodes and one cathode. Each of the former is connected to a separate side of the alternating current supply and also through reactances to one side of the load and the cathode to the other. As the current alternates, first one anode and then the other becomes positive and there is a continuous flow towards the mercury cathode thence through the load (in this case the battery to be charged) and back to the opposite side of the supply through a reactance. At each reversal the latter discharges, thus maintaining the arc until the voltage reaches the value required to maintain the current against the counter E. M. F. and also reducing the fluctuations in the direct current. In this way, a true continuous flow is obtained with very small loss in transformation.

A small electrode connected to one side of the alternating circuit is used for starting the arc. A slight tilting of the tube makes a mercury bridge between the terminal and draws an arc as soon as the tube is turned to a vertical position. The ordinary form used for vehicle batteries has a maximum current capacity of 30 amperes for charging the lead plate type and a larger form intended for use with Edison batteries yields up to a limit of 50 amperes. Those for charging ignition batteries will pass 5 amperes for one to charge six cells and a larger one that will pass 10 amperes for from three to ten batteries. As is true of the electrolytic rectifier complete instructions are furnished by the manufacturer for their use.

The Wagner device, which is shown at Fig. 227, A, operates on a new principle and comprises a small two coil transformer to reduce the line voltage to a low figure; the rectifier proper which consists of a vibrating armature in connection with an electro magnet and a resistance to limit the flow of the charging current. A meter is included as an integral part of the set for measuring the current flow. All sets are sold for use with ignition or lighting batteries of low voltage with a lamp socket plug and attaching cord, the idea being to utilize an ordinary lighting circuit of 110 volts A. C. The magnet and vibrating armature accomplish the rectification of the current with little loss, the action after

connection to the battery which is to be charged proceeding automatically. By a simple device, the current stoppage throws the main contacts open so the partially charged battery cannot be rapidly discharged. While the rectifiers are constructed to use 60 cycle, 110 volt alternating current they will work at all frequencies from 57 to 63. The size made will pass three to five amperes, the voltage being sufficient to recharge a three cell battery.

When batteries are to be charged from a direct current it is possible to use a rheostat to regulate the voltage at the terminals. The construction of a rheostat is very simple as it consists only of a group of high resistance coils of wire mounted in insulating material and having suitable connections with segments on the base plate upon which is mounted the operating arm that makes the contact. According to the manner in which these are made and wired a large resistance is introduced at first, gradually decreasing as the lever is moved over or it may operate in the reverse fashion, a large amount of current being allowed to pass at the first contact and less as the handle progresses across the path. Rheostats should only be purchased after consulting a capable electrician as the required resistance must be figured out from the voltage of the circuit to be used, the maximum battery current, the charging rate in amperes and the number of cells to be charged at one time.

By far the simplest method of charging storage batteries is by interposing a lamp bank resistance instead of the rheostat. These are easily made by any garage mechanic and are very satisfactory for charging ignition or lighting batteries. Standard carbon lamps of the voltage of the circuit shown should be used and the amperes needed for charging can be controlled by varying the candle power and the number of lamps used. If the lamps are to operate on 110 volt circuit, a 16 candle power carbon filament lamp will permit one-half ampere to pass; a 32 candle power will allow 1 ampere to pass. If it is desired, therefore, to pass three amperes through the battery, one could use 3-32 candle power lamps, or 6-16 candle power lamps. If the lamps are to burn on 220 volts it should be remembered that when the voltage is doubled the amperage is cut in half, therefore the 32 candle power, 220 volt

carbon filament bulbs will only pass half an ampere. The method of wiring is very simple as may be readily ascertained by referring to Fig. 230. The line wires are attached to a fuse block and then to a double knife switch. The switch and fuse block are usually mounted on a panel of insulating material such as slate or marble. One of the wires, the positive of the circuit, runs from the switch directly to the positive terminal of the storage

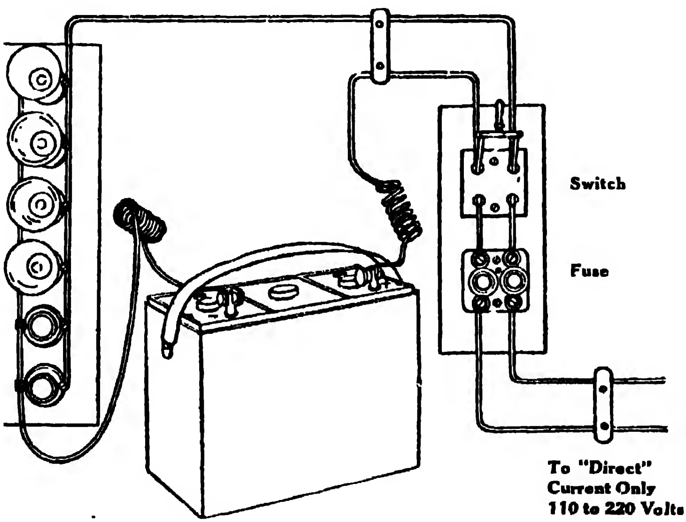


Fig. 230.—Charging Storage Battery from Direct Current.

battery. The negative wire from the switch passes to the lamp bank resistance. The lamps are placed in parallel connection with respect to each other but in series connection in respect to the battery. When coupled in this manner the current must overcome the combined resistance of the storage battery which is very low and that of the lamps. This prevents the battery being charged with current of too high voltage.

A complete commercial installation which has been used successfully with a direct current of 110 volts pressure and which

has a capacity for charging 30-6 volt batteries simultaneously is composed of two charging sets either of which may be employed independently or both may be used at same time. The method of wiring is clearly shown at Fig. 231. In this a three wire system is employed for lighting. This consists of one positive wire and two negative conductors, forming in reality two separate circuits so that one half of the installation is on one wire, while the remainder is on the other two. An upper branch is used merely for illumination. On either half of the three wire double circuit is placed a bank of lamps, these being in series with the batteries but the lamps are in multiple with each other. The board at the left has 9 sockets, that at the right 12 sockets. The number of lamps placed in these and their candle power regulate the amount of current in amperes that will pass through the battery. As we have seen, battery manufacturers advise that certain minimum and maximum charging rates be used. Assuming that the maximum is 3 amperes, to pass a current of this value through the battery, it will be necessary to screw in 6-16 candle power lamps which will average 55 watts each, which means that at a pressure of 110 volts they require a current strength of half ampere. If fitted with 16 candle power lamps the 12 socket lamp bank will pass 6 amperes, and double this amount with lamps of twice the candle power.

The meter installation shown between the charging boards is to determine the amount of current passing through the storage battery and as it is a low reading instrument, a low resistance shunt is interposed so that any overload will pass over the shunt instead of through the instrument which is calibrated to measure currents up to 30 amperes. With the small single blade knife switches in circuit the current will not pass through the instrument, as it is not advisable to include this in the circuit permanently, because the passage of current through the windings may result in injurious heating. To get a reading from either side the single blade switch is thrown off and the double throw male member of switch is placed in contact between the blades on the side of which a reading is to be taken. It will be seen that the wires are crossed at the right of the two-way switch to cause the current to flow through the instrument in the right direction and also to have

the negative terminal of each charging board at the left. This eliminates any confusion and the terminals are plainly marked so it is not possible to make a mistake when coupling batteries. When more than one battery or set of cells is being charged they are wired in series, the negative terminal of one battery being coupled to the positive terminal of the neighboring one. In connecting a battery to the charging board the negative wire should

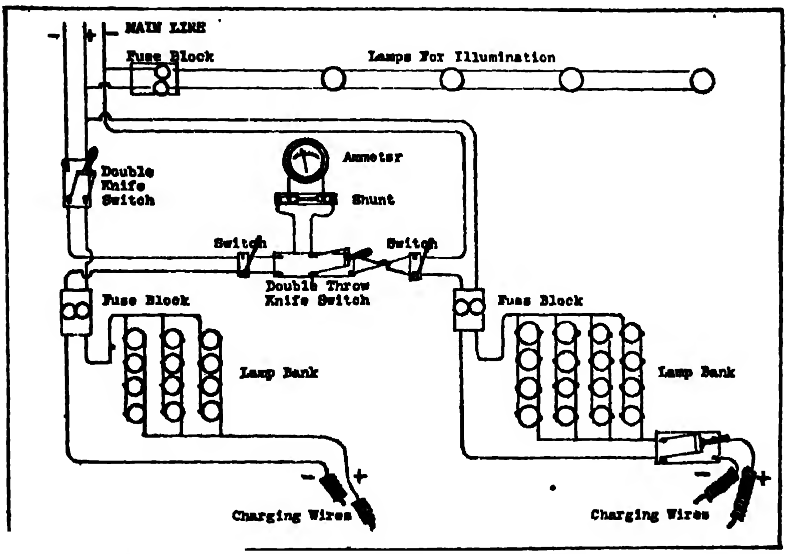


Fig. 231.—Wiring Diagram, Showing Installation for Charging Storage Battery from Direct Current, Using Lamp Bank Resistance.

always be coupled to the negative terminal of the battery and the positive wire to the corresponding battery terminal.

Features of the Edison Cell.—The instructions given apply only to batteries of the lead plate type and not to the Edison battery, which is entirely different in construction. The Edison cell uses an electrolyte consisting of 21% solution of potash in distilled water so that the electrolyte is alkaline instead of acidulous. The positive plates consist of a series of perforated steel tubes which are heavily nickel-plated and which are filled with alternate layers of nickel hydroxide and pure metallic nickel in very thin plates.

The tube is drawn from a perforated ribbon of steel, nickel-plated and has a spiral lapped seam. After being filled with active material it is reënforced with eight steel bands which prevent the tube expanding away from and breaking contact with its contents. The negative plate consists of a grid of cold rolled steel, also heavily nickel-plated, holding a number of rectangular pockets filled with powdered iron oxide. These pockets are also made up of finely perforated steel, nickel-plated. After the pockets are filled they are inserted in the grid and subjected to considerable pressure between dies which corrugate the surfaces of the pockets and forces them into positive contact with the grids. These elements are housed in a jar or container made from cold rolled steel which is thoroughly welded at the seams and heavily nickel-plated. The plates are assembled in positive and negative groups by means of threaded steel rods passing through holes in one corner of the plates and insulating washers. The terminal post is secured to the middle of the rod. The complete element or plate assembly stands on hard rubber bridges on the bottom of the can and is kept out of contact with the sides of the container by hard rubber spacers attached to the end. The can cover is also of sheet steel and contains fittings through which the electrodes pass, these being insulated from the cover by bushings of insulating material. A combined filling aperture and vent plug is secured to the center of the cover plate. For 6 volt ignition and lighting service it is necessary to use 5 cells owing to the lesser voltage of the Edison batteries. The average voltage during discharge is but 1.2 volts per cell and is not as constant as is the case with a lead battery, the voltage of which may be as high as 2.5 volts per cell.

An Edison 6.5 volt battery used for lighting or ignition may be charged completely in ten hours. A feature of the Edison battery is that overcharging at the normal rate has no harmful effects and it is advised by the maker to give the battery a 12 hour charge once every 60 days or when the electrolyte is replenished. The electrolyte must be kept sufficiently high so as to cover the plates and any loss by evaporation must be compensated for by the addition of distilled water. Another feature in which the Edison battery is superior to the lead plate type is that the

plates will not be injured if the cells are allowed to stand in a discharged condition. The external portions of the cells must be kept clean and dry because the container or can is made of a conducting material. The vent caps must be kept closed except when replacing electrolyte or bringing the level up to the proper height by adding distilled water. Care should be taken to avoid short circuiting of the battery by tools or metal objects and special emphasis is laid on the precaution that no acid or electrolyte containing acid be poured into the cells. It is said that the Edison battery has a longer life than the lead plate type of equal capacity.

Winter Care of Storage Batteries.—It would not do simply to leave the battery in the car for a period of, say, 4 or 5 months without giving it any care or attention, for in that case at the end of that time it would be found to have its plates so thickly covered with lead sulphate as to make it practically useless. For storage batteries "to rest is to rust" and become ruined, unless special precautions are taken. Automobile storage batteries are all or nearly all of the sealed-in type from which the elements cannot be removed without a great deal of trouble. Therefore, the only method of keeping the plates intact consists in charging the battery at intervals of about two weeks. The following advice concerning the care of batteries during a protracted period of idleness of the car is due to the Willard Storage Battery Co., and refers especially to the batteries of starting and lighting systems.

At intervals of 2 weeks the engine should be run until the electrolyte shows a specific gravity of 1.280. If this is done regularly the engine need be run only about an hour each time. But if the owner should not be in possession of an hydrometer, it is better to run the engine for 2 or 3 hours each time, for the sake of safety. To charge the battery properly the engine should be run at a speed corresponding to a car speed of about 20 mph on the direct drive. There may be cases, however, where the owner is compelled to store his car in a space where it is practically impossible to run the engine. Where this is the case, it is recommended, if electric current is available, that the owner purchase a rectifier or small charging machine. A charge over night, or

for about 12 hours, every 2 weeks with this apparatus will be sufficient to keep the battery in a healthy condition. Before beginning the charging the battery should be inspected to see if it is filled with solution. If the solution needs replenishing, distilled water should be added until the solution fully covers the plates, which may be determined by removing the vent plugs and looking down into the cells. In case it is impossible to run the engine for charging and the owner does not care to incur the expense of purchasing a rectifier, he should remove the battery from the car and arrange for its storage at a garage which has charging facilities, stipulating that it must be charged every 2 weeks. The cost of having it so cared for will be nominal and will prove excellent insurance against deterioration.

To care for storage batteries of a type that is easily taken apart the following method is recommended: First charge the battery until every cell is in a state of complete charge. If there should be any short circuited cells they should be put into condition before the charge is commenced, so that they will receive the full benefit of the charge. Then remove the elements from the jars, separating the positive from the negative groups, and place in water for about 1 hour to dissolve out any electrolyte adhering to the plates. Then withdraw the groups and allow them to drain and dry. The positives when dry are ready to be put away. If the negatives in drying become hot enough to steam, they should be rinsed or sprinkled again with clean water and then allowed to dry thoroughly. When dry, the negatives should be replaced in the electrolyte (of from 1.275 to 1.300 specific gravity), care being taken to immerse them completely and allow them to soak for 3 or 4 hours. Two groups may be placed in a jar and the jar filled with electrolyte. After rinsing and drying the plates are ready to be put away.

The rubber separators should be rinsed in water. Wood separators after having been in service, will not stand much handling and had better be thrown away. If it is thought worth while to keep them they must be immersed in water or weak electrolyte, and in reassembling the electrolyte must be put into the cells immediately, as wet wood separators must not stand exposed to the

air for any unnecessary moment, especially when in contact with plates. Storage batteries always should be stored in a dry place, preferably in one where the temperature will never fall below 40° Fahr. Storage battery solution or electrolyte varies greatly in density between the points of complete charge and complete discharge. When completely discharged the electrolyte of the average battery has a specific gravity of 1.14, and a sulphuric acid solution of 1.14 specific gravity has a freezing point of about 10° Fahr. Therefore, if a completely discharged battery is allowed to stand where it is exposed to extremely low temperature it is quite possible for the electrolyte to freeze and the cells to be injured in consequence. However, as already pointed out, a battery for other reasons must not be allowed to stand in the discharged condition for any length of time. With increasing charge the density of the electrolyte increases until, when the charge is complete, it attains 1.28 specific gravity. The freezing temperature of the solution drops very quickly as the specific gravity increases, somewhat as follows:

Spec. Grav.	Freez. Point Degrees
1.14	+10
1.16	+ 5
1.175	— 4
1.20	—16
1.225	—36
1.25	—60
1.28	—85

Consequently there is no possibility of a storage battery being injured by freezing in this latitude if it is kept in a fair state of charge.

Timer Defects and Restoration.—In any high tension ignition system the primary circuit either of the battery or the magneto must be interrupted at stated times in order to produce the spark necessary to ignite the gaseous charge at the instant of maximum compression or when the piston reaches the end of its up stroke. A timer is really a mechanically operated switch capable of establishing a large number of contacts per minute without undue depreciation. The timer shown at Fig. 232, is used on the Ford

motor and is the surviving type of numerous designs that have been made for this purpose. This device is sometimes called a "commutator" and consists of an aluminum case circular in form and having a projecting bushing or passage through which the camshaft of the motor extends. The contact is established by a revolving arm which carries a roller that makes contact with seg-

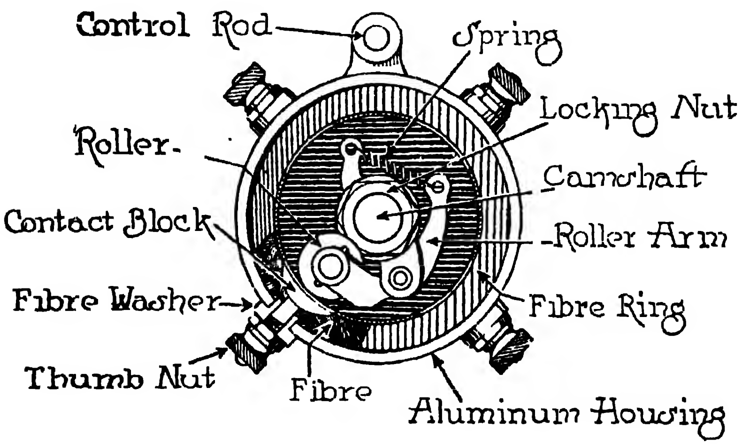


Fig. 232.—Timer Used on Ford Automobiles.

ments or blocks imbedded in a fibre ring which serves to insulate them from the metal parts of the timer.

The number of contact segments and their placing depends upon the number of cylinders it is necessary to ignite. On a four cylinder motor four contact blocks are used, spaced 90 degrees apart. For a two cylinder motor of the form ordinarily applied to automobiles but two of the blocks would be used, spaced on halves of the circle or 180 degrees apart. For a three cylinder motor three contact segments would be needed, each separated from the other by a space of 120 degrees. On a six cylinder engine there would be one contact for each cylinder which would mean that the contact blocks would be separated by spaces of 60

degrees. The rotary portion of the timer usually revolves at camshaft speed and should be timed in such a way that when the piston in cylinder No. 1 is at the top of its compression stroke the roller will be in contact with the segment that is connected to No. 1 spark coil by a wire. The arrangement of the remaining terminals depends upon the firing order of the motor. For instance, if it is 1, 2, 4, 3, the next terminal in the direction of roller arm rotation would be coupled to coil unit No. 2, that following to coil unit No. 4, and the remaining terminal to coil unit No. 3.

When a timer of this form is used, ignition is apt to be irregular should the spring attached to the free end of the roller arm break. If the interior of the device is filled with dirty oil, the current is apt to be short circuited. If the device has been oiled with a lubricant having too much body, the roller is not apt to make good contact with the metal segments and ignition will be erratic. Depreciation in the bearing pin on which the roller rotates or of the fulcrum pin on which the roller arm swings will also result in irregular ignition. If the motor runs steadily at low speeds but misses fire at high speeds, and the trouble has been traced to the timer, it is necessary to feel around the inside of the fiber ring with the finger to see that this is smooth and perfectly round, and that the contact block faces are flush with the surface of the ring. If the blocks are worn below the surface of the ring, the roller is apt to jump the space at high speeds, due to the low block, and not establish an electrical contact. At low speeds the tension of the spring is sufficient to keep the roller bearing against the contact blocks, as it will follow the irregular contour of the timer interior without difficulty. If the segments are badly worn and the fiber ring roughened, the timer casing should be chucked in a lathe or grinding machine and the interior ground smooth and perfectly round with a small emery wheel. The writer has seen some mechanics attempt to take a light chip out of the timer interior, as they were ignorant of the fact that the contact blocks were of tool steel and hardened. A fast-running, free-cutting emery wheel is the best tool to use for smoothing down hardened steel segments. The stem or bolt attached to the contact block must pass through a fiber washer or bushing in

order that it be insulated from the timer body. If these bushings crack, there may be an opportunity for leakage of current, especially on the Ford car, where the ignition current is derived from the magneto and is stronger than that usually produced by a chemical battery.

Another form of timer is shown at Fig. 233. In this the contact is established between balls and a contact roller. In order to eliminate the wear that is unavoidable with plain bearing timers

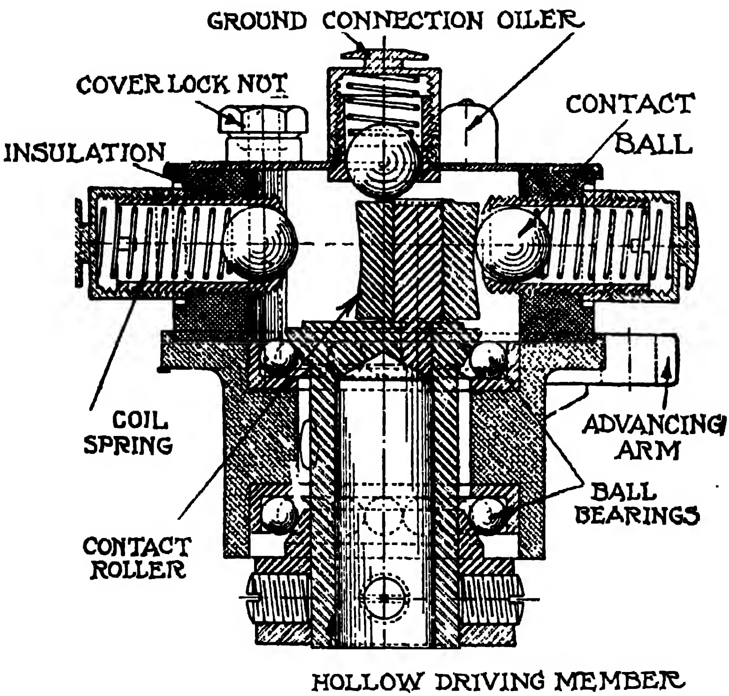


Fig. 233.—Showing Construction of Ball Contact Timer.

the casing carries ball bearings which are used to support the central hollow revolving member. Some timers of the form shown at Fig. 232 are fitted with a plain bearing which wears after the timer has been used and which produces irregular ignition due to a poor ground contact. Battery timers of the forms out-

lined are seldom used at the present time, as they have been succeeded by the more efficient short contact types. A notable exception to this almost general rule is the Ford car, which is manufactured in immense quantities and which utilizes the roller contact timer previously described.

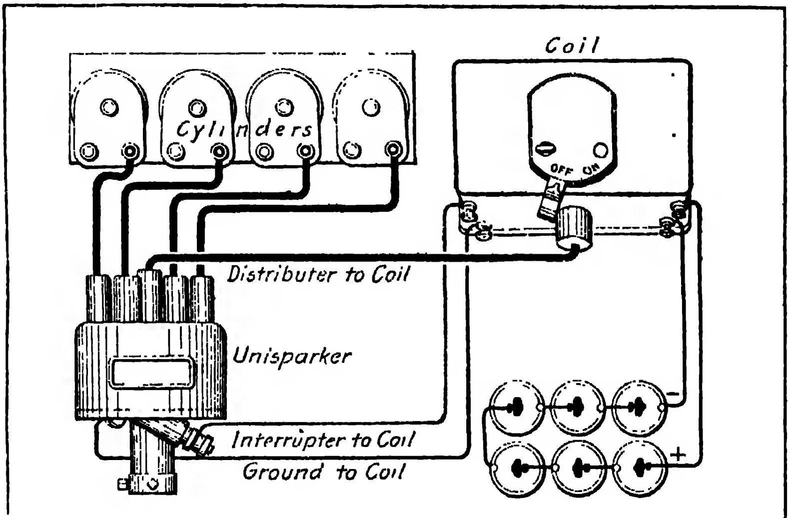


Fig. 234.—Atwater Kent Uni-Sparker System.

One of the best known of the short contact forms of timer is the Atwater-Kent, which is usually combined with a secondary distributor as shown at Fig. 235. The met. od of placing this timing and distributing member in circuit is clearly shown in wiring diagram Fig. 234. The advantage of a timer of the form shown, as contrasted to the simple type previously considered, is that a one unit induction coil will serve any number of cylinders from 2 to 8, whereas with the roller type shown at Fig. 232 a separate induction coil is needed for each cylinder to be fired. It will be observed that the coil used with the Atwater-Kent system has five terminals, four of these being primary terminals, one at the center of the coil box a secondary or high tension terminal. A set of six dry cells connected in series is wired to one

side of the coil box as indicated. One of the two remaining primary terminals runs to the primary contact at the bottom of the interrupter, the other to a grounding screw attached to the interrupter casing. The secondary terminal is connected to the central terminal of the distributor, while the remaining four terminals are joined to the plugs in the engine cylinders in such order as to insure proper sequence of explosions. The external view of

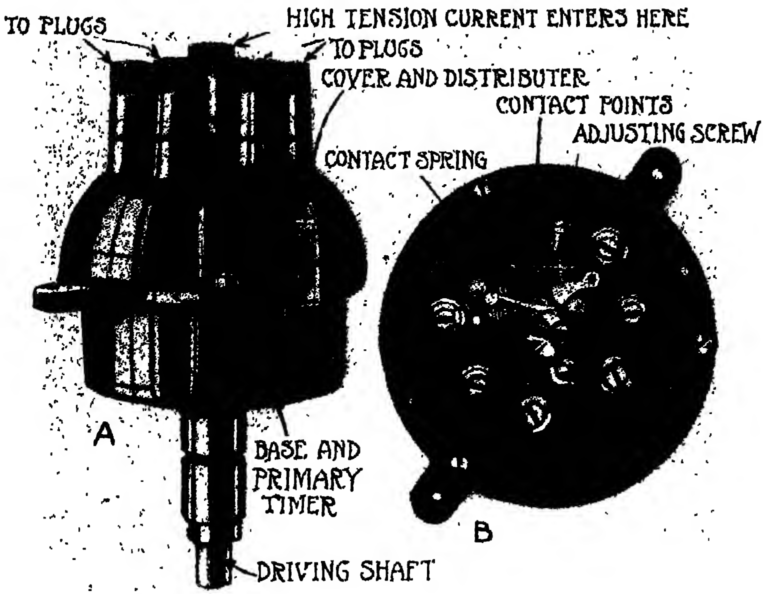


Fig. 235.—Showing Construction of Atwater Kent Uni-Sparker.

the Atwater-Kent uni-sparker is shown at Fig. 235, A. In this a centrifugal mechanism is contained in the lower part of the casing by which the spark is automatically advanced as the speed of the engine increases.

The only points that will wear on a device of this character are the contact points which are clearly shown in the view of the contact breaker mechanism at B. The revolving shaft in the center has a number of notches, two, three, four, six, or eight,

according to the number of cylinders to be fired, cut into it. A light, hardened steel trigger is held against the shaft at this point by a small spring. On turning the shaft this trigger is carried forward by the notches in the shaft, and is suddenly released as the hook end leaves the notch. In so doing the back of the trigger strikes a small pivoted hammer situated between the trigger and the spring carrying the contact points. This causes the contact points to open and close with remarkable rapidity, but one contact being made for each spark. When it is desired to adjust the platinum contact points, as when they show signs of wear, it is only necessary to remove one or more of a number of extremely thin washers under the head of the adjustment screw and to replace the screw. The contact points should be absolutely clean and bright and have smooth contacting surfaces. The distributor portion of the device consists of a hard rubber block fitted to the top of the primary shaft, this carrying a brass quadrant that passes the high tension current to the spark plugs by means of the terminal points imbedded in the hemispherical cover. There is no actual contact between the rotating quadrant and the distributor points, as the high tension current is capable of jumping the very slight gap that exists between them. Owing to there being no actual contact, there will be no depreciation in the distributor or upper portion. The center terminal, which is in connection with the induction coil, is a combination of carbon and brass, and a light, flat spring on the quadrant bears against it to maintain positive electrical connection. The distributor cover is easily removed without the use of tools, as it is held by spring clips. Location or dowel pins in its lower edge insure that it will be replaced in the correct position.

One of the most popular of the combined starting, lighting and ignition systems is the Delco, which is shown at Fig. 236. For the present we will concern ourselves merely with discussing the ignition functions of the system, leaving the self-starting and electric lighting features for more comprehensive consideration in the following chapter. Current is produced by a one unit type motor-generator, although the windings of the device when operated as a motor or a generator are entirely separate. The ignition

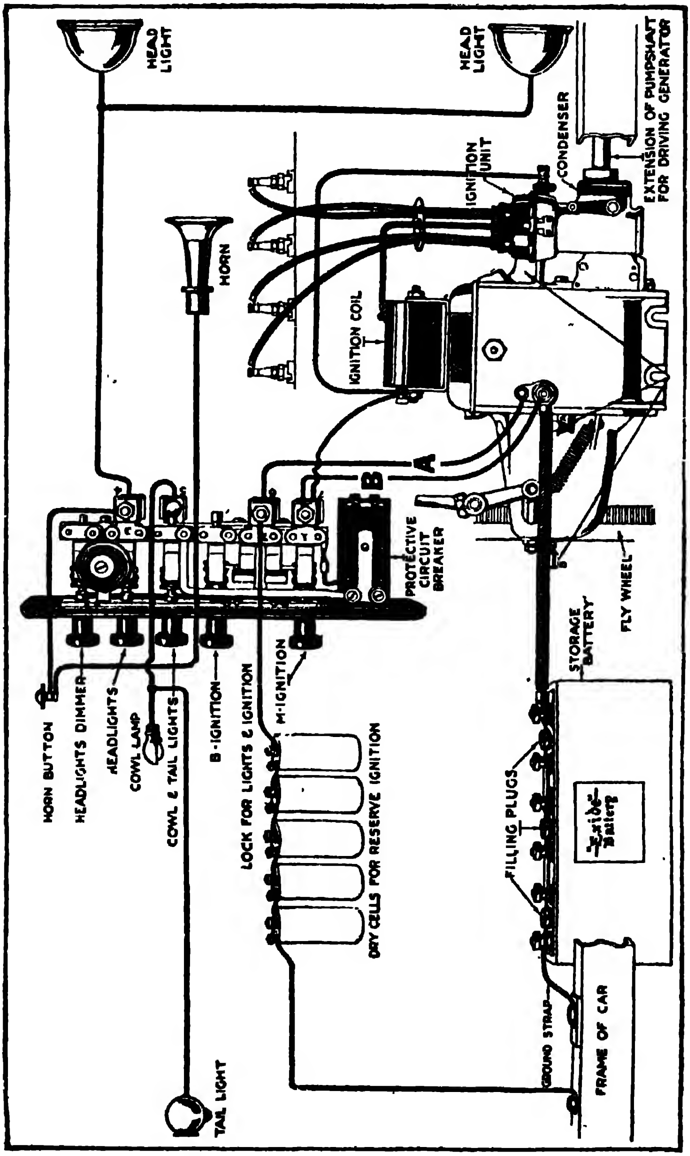


Fig. 236.—The Delco Ignition, Motor Starting and Car Lighting System.

urrent is obtained either from a storage battery which is kept in ı state of charge by the generator, or from a set of dry cells which are carried for reserve ignition. The ignition system consists of a one unit non-vibrator coil, sometimes attached to the top of the motor generator, as shown at Fig. 236, though it may be placed at any convenient part of the car and a dual automatic listributor and timer usually included as a part of the device as shown. When ignition current is supplied from the lighting circuit the current passes from the storage battery through a switch and out to the low tension winding of the coil, from whence it passes to the timer and from there to the frame, where it is grounded. The high tension current generated in the coil runs o the distributor, where it is switched to the spark plug in the lifferent cylinders in turn.

When dry cells are used for ignition the operation is the same except that a device called "the ignition relay," and shown at the right of Fig. 238, is added to the circuit. The function of this device is to break the circuit immediately after it has been completed by the contact points of the timer, which is shown at the left. The use of the ignition relay results in a material saving of the battery current as the circuit is closed a much shorter time than is the case when the circuit is broken by the timer contacts themselves. The operation of the relay is not difficult to understand. The magnet A attracts the armature B when the circuit is completed through the timer. This action opens contact C and breaks the timer circuit. A condenser D is mounted besides the magnet coil A, in order to absorb the current produced by self-induction in the magnet winding, which would be apt to produce a hot spark between the contact points when they were separated if no means were taken for its disposal. The adjustment of the relay is at the pole piece E. This regulates the distance between the armature B and the magnet pole, and the gap between the contacts C. The adjustment is made by turning the notched head at E clockwise to increase, anti-clockwise to decrease, the gap between the contacts. The correct distance between contacts C when the armature B is pressed down is equal to approximately the thickness of one sheet of newspaper. A very simple way in which

the adjustment can be made when the engine is running on the battery is to turn the notched head of the pole piece in the counter-clockwise direction until the motor ceases to fire. Then turn it four or five notches in the opposite direction. Under no conditions should the adjustment screw be turned very far in either direction. If the armature vibrates feebly when the starting but-

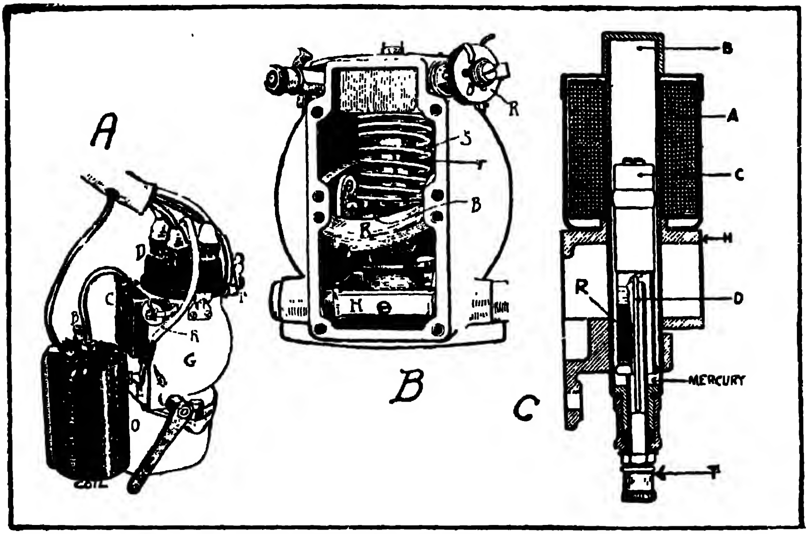


Fig. 237.—Some of the Regulating Devices Used with the Delco System.

ton is pressed it indicates either weak dry cells or dirt between the relay or timer contacts.

The interior arrangement of a timer for both dry cells and storage battery current is shown at Fig. 238. The cam C is driven by a rotating shaft and establishes contact between the points when the cam rider rises on the point of the cam. When the cam rider drops into the notch between the high points the contact points separate. The same instructions that have been given for the contact points of the Atwater-Kent timer apply just as well in this case. While the contact points are but one-eighth inch in diameter, it is said that many thousands of miles of service may be obtained without readjusting. It is important that the

contact spring, which is the straight one carrying the platinum point, should have a good tension outward against the cam rider member below it. It is said that this spring should be capable of supporting the weight of half a pound. If the tension is not sufficiently great the contact points barely break contact which permits the spark to arc between them, tending to burn them.

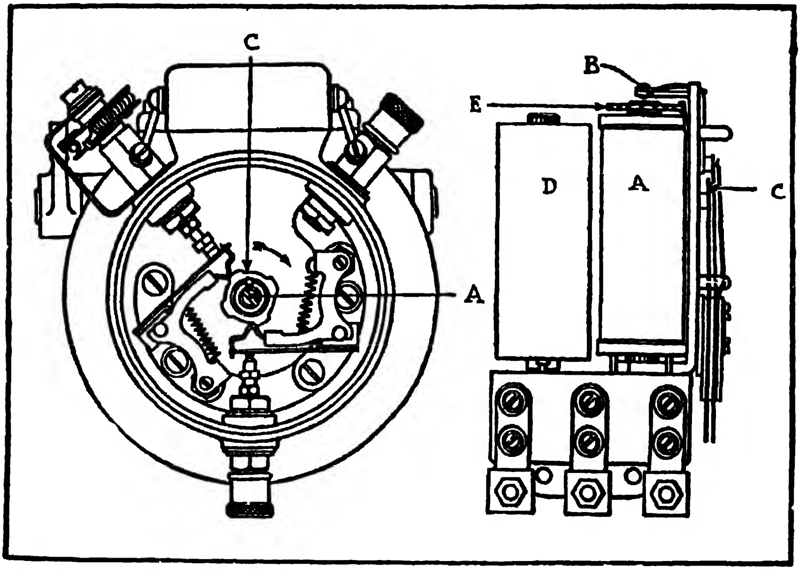


Fig. 238.—Short Contact Timer and Ignition Relay Used with the Delco System.

The contact should be so adjusted that the contact spring is forced away from the breaker member at least half the distance of the T-slot on the vertical part of the cam rider, when the latter is on the contact lobe of the cam. The contact points should open about ten one-thousandths (.010 inch) inch when the contact arm rests upon the back stop. The contact arm should clear the cam except at the contact lobe. A short wire connects the two posts of the breaker arms and this connection should always be inspected when making adjustments to insure that it has not been disturbed. It is said that if this wire is disconnected the current will pass

through the contact spring, impairing its tension. Whenever the contact points are cleaned care should be taken to have the surfaces parallel.

In some of the Delco ignition systems an automatic spark advance mechanism is used. The usual method of wiring when the distributor is a separate member from the generator is shown at A, the left of Fig. 237. The construction of the automatic spark advance mechanism is shown at B. In this the shaft which transmits motion to the timer is in the form of a tube T, revolved by spiral gears. An inclined slot is cut through the walls of this hollow driving member. A smaller shaft is carried inside of the hollow member, and a vertical slot is cut through this shaft in order to permit a pin to pass through it, said pin being actuated by a collar adapted to slide up and down on the outside of the hollow driving shaft. The pin passes through both the straight slot in the small shaft and the incline slot in the hollow driving member. If the collar holding the pin is moved it will change its angular relation with the small shaft which will advance the timing cam of the contact breaker. The collar is shifted by a spring loaded revolving ring R, which moves from the position shown in the drawing to a horizontal position as the speed increases. This ring is connected to the sliding collar and causes it to rise, advancing the spark as the engine speeds up or to fall, retarding the spark as the engine speed decreases. If desired, the spark timing may be controlled independently of the automatic advance mechanism by a spark lever connected to the corresponding member on the steering wheel.

In some of the Delco systems a voltage regulator such as shown at C, Fig. 237, is used. The function of this device is to prevent too much current flowing to the storage battery when the engine is running at high speed. As the voltage of the storage battery will vary with its condition of charge the intensity of the magnetic pull exerted by the solenoid A upon the plunger C varies and causes a contact attached to the plunger to move in and out of the mercury which is contained in the bottom of the mercury tube B. When the battery is in a discharged condition the plunger C assumes a low position in the mercury tube, and when in this posi-

tion the coil of resistance wire carried upon the lower portion is immersed in the mercury, and as the plunger rises the coil is withdrawn. As the plunger is withdrawn from the mercury more resistance is thrown into the circuit and the greater resistance causes the amount of current flowing to the battery to be gradually reduced as the battery nears the state of complete charge until finally the plunger is almost completely withdrawn from the mercury, throwing the entire length of the resistance coil into the shunt field circuit, thus causing an electrical balance between the battery and the generator and eliminating any possibility of overcharging the battery. A description of the voltage regulator follows: A solenoid coil A surrounds the upper half of a mercury-containing tube B. A plunger C, comprising an iron tube with a coil of resistance wire R wrapped around the lower portion on top of mica insulation, is adapted to be drawn up into the solenoid as the battery current increases in strength. One end of this resistance coil is attached to the lower end of the tube, the other end being connected to a rod B in the center of the plunger. The lower portion of the mercury tube is divided into two concentric wells by an insulating member, the plunger tube being partly immersed in the outer well and the rod in the inner well. The space in the mercury tube above the mercury is filled with a special oil, which serves to lubricate the plunger as well as protect the mercury from oxidation. The device is connected to the shunt field of the generator so that the current must follow a path leading into the outer well of mercury through the resistance coil R to the rods carried at the center of the plunger, from thence into the center well of mercury and out of the regulator. The more the resistance coil R is pulled out of the mercury the more resistance is interposed in the field circuit and a smaller amount of the generator current is going to charge the storage battery.

It will be noticed that in the wiring diagram shown at Fig. 236 a protective circuit breaker is attached to the switchboard. The function of this device is to open the circuit between the source of current supply (generator and storage battery) and the current consuming units (lamps, horn and ignition apparatus)

if one of the wires leading to a current consuming unit happens to become grounded. Under such a condition an excessive flow of current is possible on account of the lessened resistance of the circuit. Such a flow goes through the winding of the circuit breaking relay or protected circuit breaker, which produces a magnetic pull that opens the contact and cuts off the current supply. As soon as the contact is opened the magnetic pull ceases and the contact is closed again, re-establishing the magnetic pull and again opening the contact. The circuit breaker will continue to vibrate until the ground or short circuit is located and corrected whenever any one of the switches controlling the current consuming units is pushed in to establish a circuit. The function of this protective circuit breaker is the same as a fuse block and fuse except that it is not necessary to keep replacing fuses.

Battery Ignition Systems.--Because of the almost universal employment of electricity for lighting and starting systems, the battery ignition system has been improved materially inasmuch as the storage battery supplying the current is constantly charged by a generator. A number of systems has been devised, these operating on two different principles, the open circuit, such as the Atwater-Kent, previously described, and the closed circuit. An example of the closed circuit system is shown at C, Fig. 239, and is of Connecticut design, the complete ignition system consisting of a combined timer and high tension distributor, a separate induction coil and a switch. The system is distinctive in that the timer is so constructed that the primary circuit of the coil is permitted to become thoroughly saturated with electricity before the points separate, with a result that a spark of maximum intensity is produced. The action is very much the same as that of a magneto on account of the saturation of the winding. Another feature is the incorporation with the switch of a thermostatically operated electro-magnetic device which automatically breaks the connection between the battery and the coil should the switch be left on with the motor idle.

The contact breaker mechanism consists of an arm A carrying one contact, a stationary block B carrying the other contact, a

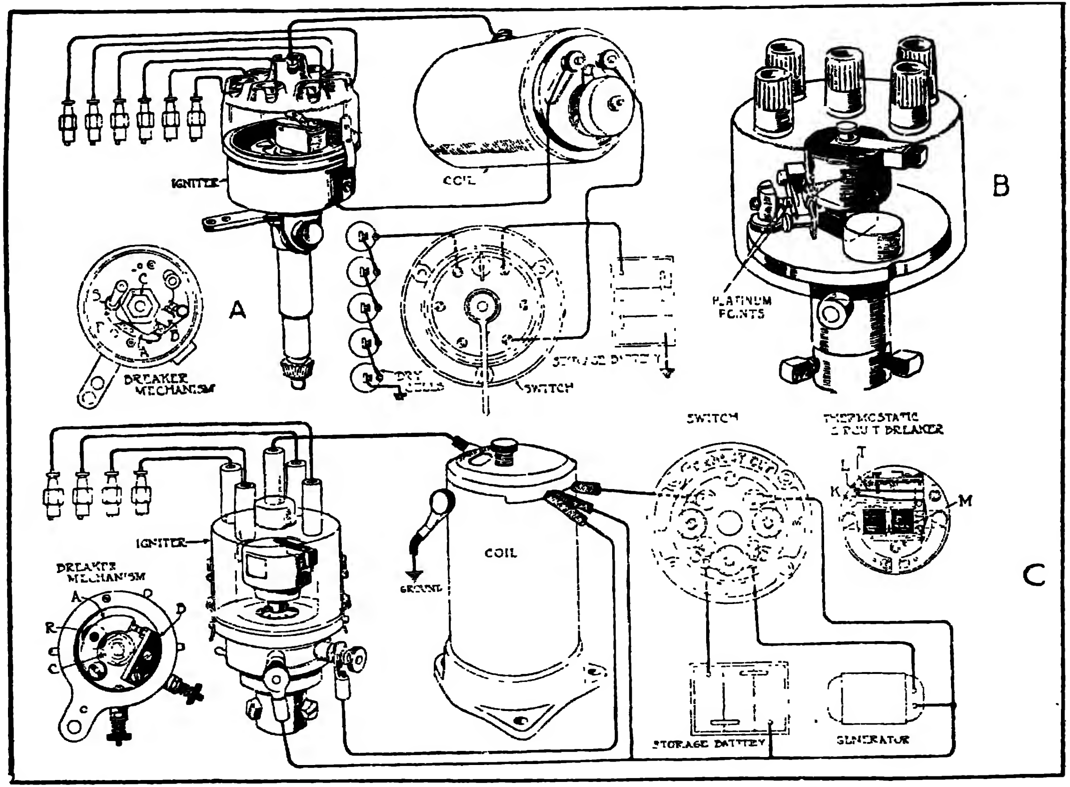
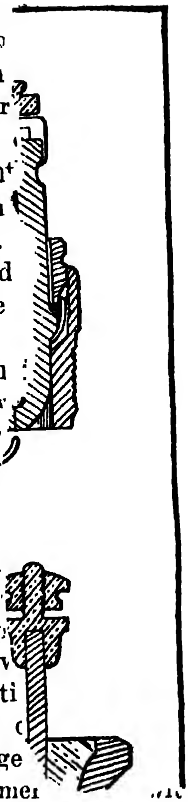


Fig. 239.—Typical Short Contact and Closed Circuit Battery Ignition Systems.

fiber roller R which is carried by the arm A and c
on the cam C, which is mounted on the driving
the contacts are held together under the action o
As the four cams, which in touching the rolle- R 1
separate the contacts, are 90 degrees for a four
the period of saturation of the coil or the length
rent flows through it to the battery is sufficient
when the points have separated the current wh
up induces an intensely hot spark at the plugs.
vantage inasmuch as it insures prompt starting and
at low engine speed as well as providing positive
engine speed.



The thermostatic circuit breaking mechanism
This consists of the thermostat T, which heats v
passes through it for from thirty se ls to four
interruption, and thus is bent l, making
contact L. This compl .cal circuit
the magnets M, causir k to operate
an electric bell. Thi ikes against the pla
whichever of the t ons in the switch may b

As will be d, the transformer coil p
terminals. Or these is connected directly v
the other leads to the central secondary distributi
timer-distributor. Of the three primary leads, c
switch, one to the wire leading from the storage
timer, and one directly to a terminal on the timer
is provided with three buttons, the one marked B being depresse
to start the engine, as the ignition current is then drawn from th
storage battery. After the engine has been started the button
marked M is pressed in, this taking the current directly from the
generator. To interrupt ignition the button "off" is pressed in,
this releasing whichever of the buttons, B or M, is depressed. Four
wires run from the distributor section of the igniter to the spark
plug.

The Remy system also operates on the closed circuit princip
and is shown at A, Fig. 239, in a form adapted for six-cylinder
engine ignition. The transformer coil is of the three terminal type,

in order to form a seating for tlntral secondary distributing brush at A is the type of plug most fry is joined to the primary contact effective design. It is easier of the igniter. The remaining coil of the body than in the forritch. One of the poles of the storage end and which must be disries of dry connected cell batteries are deposit from the insulathe other two the wires run to the switch a very fine wi current may thus be derived either from the dry which is in c for emergency or from the storage battery for regular to transmit oses. The construction of the timer which incor- The theory o breaker mechanism is clearly shown. The movable is not so apt ntact point is carried by the arm A, which fulcrums trode forms ng S, and which has a piece of hard steel F riveted that might sl a cam rider. The cam C is of hexagonal form,

The plugs s ints which separate the contacts when they ride porcelain. Whe attached to the arm A. The fixed platinum con- around the cen s so arranged that it may be adjusted by moving of mica washers nditions demand. It is to this member that the form a smooth al of the coil is connected.

keted using glas ombined timer distributor known as the Halladay general princip Fig. 239. The make and bre mechanism is very lator instead of gn, as is the distributing me sm. The contact porcelain insul platinum points is established by a four point cam. insulators are y current is distributed from the central terminal to to short circu ibuting terminals by a carbon brush very much simi- of jumping to that employed in a high tension magneto. This operates on the open circuit principle.

Spark Plug Faults.—The part of the ignition system that is apt to give the most trouble, and for the most part through no fault of its own, is the spark plug which is placed in the combustion chamber in order to permit a spark to take place between the electrodes whenever it is necessary to explode a charge of gas. Spark plugs are made in infinite variety, some representative simple forms being shown at Fig. 240. Those in section at A, B and C utilize a porcelain insulator through which a central rod or electrode passes. This terminates at the top in a threaded member, to which the thumb nut is screwed. In most plugs using porcelain insulators a cap is cemented to the top of the porcelain

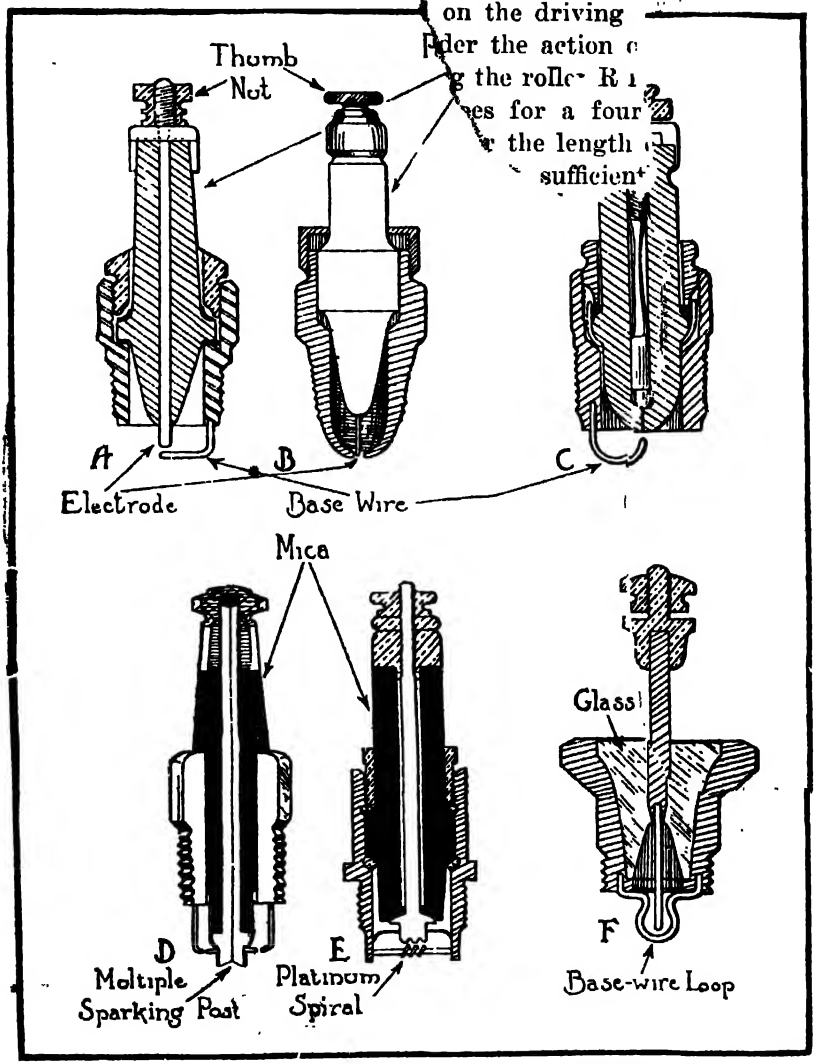


Fig. 240.—Showing Construction of Typical Spark Plugs.

in order to form a seating for the thumb nuts. The form outlined at A is the type of plug most generally used, as it is a simple and effective design. It is easier to clean the points or the interior of the body than in the form shown at B, which has a closed end and which must be dismembered in order to remove the sooty deposit from the insulator surface. The type of plug at C has a very fine wire imbedded in the lower portion of the porcelain, which is in connection with a conductor of heavier material used to transmit the current from the terminal nuts to the fine wire. The theory of action of a plug of this nature is that the fine wire is not so apt to be short circuited by soot as the projecting electrode forms are, and that the spark tends to clear away material that might short circuit the current by burning it.

The plugs shown at D and E have mica insulators instead of porcelain. When mica is used a sheet of that material is wrapped around the central electrode several times, after which a series of mica washers is clamped tightly together and turned down to form a smooth insulator. The plug at F is the only one marketed using glass insulation. Other plug forms made on the same general principles as that at A use lava or steatite as an insulator instead of the porcelain or mica. For all-around service the porcelain insulator gives the best results, as the mica and lava insulators are apt to become oil soaked and permit the current to short circuit through the insulator and the plug body instead of jumping the air gap. Another representative form of spark plug showing the proper space between the spark points is shown at Fig. 241, A.

The plug at B is one that combines a priming feature and is intended for use in engines of the Ford type in which no provision is made for using priming cups or compression relief cocks. The plug body is formed in such a way that a needle valve fitting may be screwed into it, this being intended to close a passageway communicating from a channel around the top of the plug body to the interior of the plug body. It is said that if this needle valve is opened for a minute or so while the engine is running that there will be a tendency to clear the plug points of any loose oil or carbon. The compression may be relieved by opening the

needle valve, and if it is desired to inject gasoline into the cylinder to promote easy starting this may be easily done by filling the channel or groove on top of the plug body with the fuel, then opening the needle valve to allow it to pass to the plug interior. The gasoline will run down the walls and collect around the spark points, where it will be readily ignited by the spark.

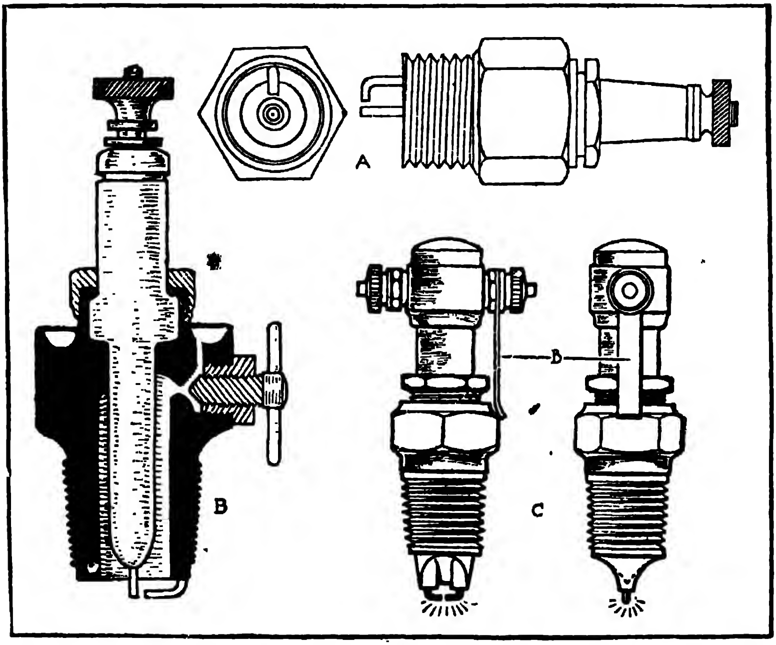


Fig. 241.—Spark Plug with Priming Arrangement and Two Pole Spark Plugs.

It is sometimes desirable to have two sparks occur in the cylinder at the same time, especially on engines of the T-head form used for racing. One spark plug of the special form shown at C is used in connection with a regular spark plug of the form shown at A, the special plug being placed first in the circuit and joined to the regular plug by a length of wire bridging the free terminal of the plug at C with that on top of the insulator of the regular pattern. As the plugs are in series, the current must jump the

gap of both plugs and thus two sparks occur, which is said to increase power by accelerating the rate of flame propagation, which of course results in more energetic ignition. The insulator is shaped to form a double V, the sides being slightly concave and larger than the center V, which ends in a sharp point. This construction is said to cause the point to be self-cleaning by the explosion. Two electrodes pass through the insulating member instead of one, these being insulated from each other and the plug body as well. The high tension current enters one terminal and passes down one of the electrodes, jumps the air gap, and can only reach the ground if the terminal connected to the second electrode is in electrical connection with the terminal of an ordinary form of spark plug or if it is bridged down to the plug body by the keeper B. When this keeper is in place, as indicated, the plug will act the same as a single electrode sparker. When the plug is to be used for double ignition in connection with one of the regular forms, the keeper B should be removed and a short wire used to join the terminal to which the keeper was attached to the terminal of the regular pattern spark plug.

Spark plug troubles are not hard to locate, as they may be readily determined on inspection. If an engine misses fire, i.e., runs irregularly, it is necessary to locate the spark plug at fault in order to remove it for inspection or cleaning. The common method of doing this is to short circuit the spark plug terminal with some metallic portion of the engine by using a wood handle screw driver, as shown at Fig. 242, A. Each plug is tried in turn, and when a good one is short circuited the engine will run even slower than before. If a plug is short circuited and the engine does not run any slower or work differently, one may assume that the plug is defective or that the cylinder is not firing for some other reason. A very simple spark plug tester which can be made by any repairman for use on cars employing magneto ignition or high tension battery-distributor ignition, is shown at Fig. 242, B. This consists of two strips of brass riveted together at one end and fitted into a fiber or hard rubber handle. The brass strips are spread apart so that contact may be made between the plug body and insulated central terminal of practically any size plug. When

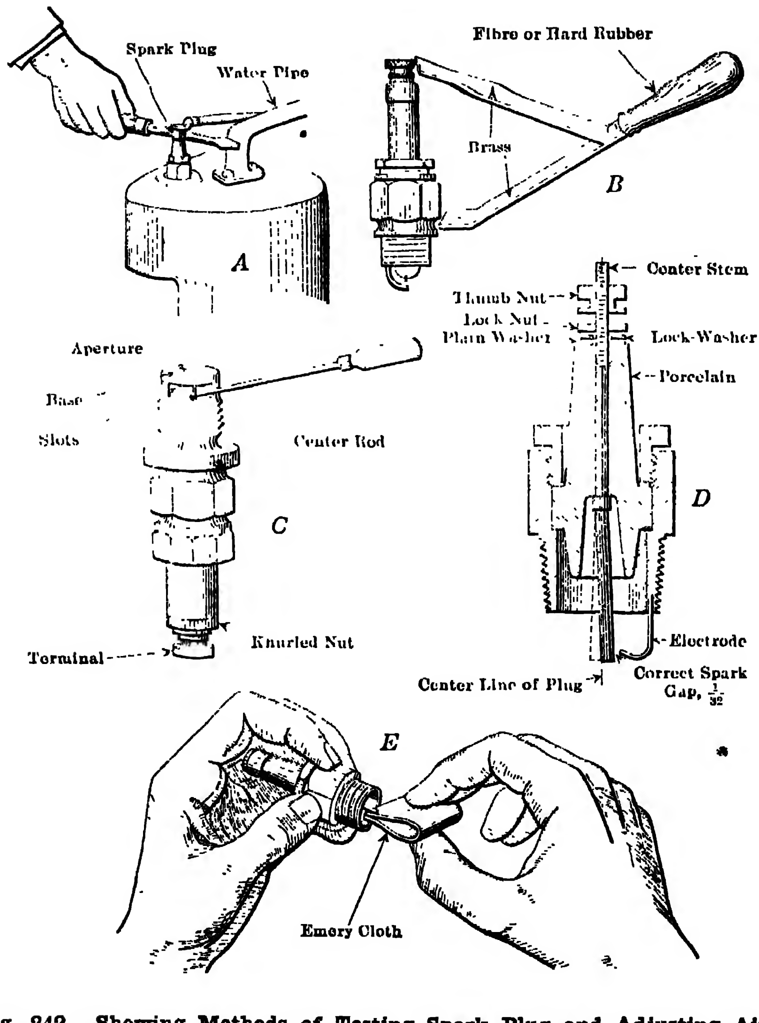


Fig. 242.—Showing Methods of Testing Spark Plug and Adjusting Air Gap Between the Electrodes.

a four-cylinder or six-cylinder engine uses individual spark coils for ignition, it is possible to detect the missing cylinder by holding down the coil vibrators with the fingers, leaving the engine to run

on one of the coil units or one cylinder as the others are cut out. Each coil unit is tried in turn, and when all others are rendered inoperative except the defective one or the coil leading to the defective spark plug, the engine will stop. The wire leading from the spark coil is traced to the spark plug, and that member removed for examination. The common trouble is a deposit of burnt oil or carbon around the insulator and between the plug points. This short circuits the current as it provides an easier path for the passage of electricity than the air gap does. If the points are too close together the plug will become short circuited very quickly and ignition is apt to be erratic because the spark does not have sufficient heat to ignite the mixture. If the spark points are too far apart the resistance is apt to be too great for the current to jump the air gap. The porcelain may crack or become broken, in which case the current is apt to short circuit if the break is down in the plug body. If a mica or lava insulator becomes oil soaked. this also will produce short circuit.

Most plugs are of the easily separable form, as shown at Fig. 240, A, in which case the insulator may be easily removed by unscrewing the packing nuts that keep it seated against the plug body. If the plug is clean when examined the thing to do is to see that the spark gap is correct. This should be about one-thirty-second inch. Whenever a spark plug is to be put into use, whether it is a new one or old one which has been cleaned, the spark points should always be set so there is a gap of about the thickness of a smooth ten-cent piece between them. The method of obtaining a correct spark gap depends entirely upon the type of the plug. In the plug shown at Fig. 242, C, which has a plate at the end, it is necessary to bend over the center stem by using a small screw driver or similar tool as indicated. With a plug of the form shown at D the center stem is bent the proper distance away from the small hook-shaped wire or electrode which projects from the bottom of the spark plug body. In some plugs it is easier to bend the central stem than the side electrode, as the latter is of hard material, whereas in others it is not possible to bend the central electrode and the point attached to the plug body must be bent instead. It is important when replacing the por-

celain insulator after cleaning to make sure that the packing nut is drawn down quite tight in order that the joint will be tight enough to hold the explosion pressure. It is also necessary to screw down the small hexagon lock nut on top of the spark plug porcelain, as if this is left loose the center stem of the plug will be free to turn in the porcelain, especially if the thumb nut or terminal is being tightened. It will be apparent that if the center stem is bent over toward the side electrode in the manner shown at D, that if it is turned a very small part of a circle the size of the gap between the center stem and side electrode will be altered appreciably. If the porcelain is found covered with oil and carbon when removed, it should be thoroughly cleaned, care being taken not to scratch the glazing on the porcelain surface, as if this glaze is destroyed it will be possible for the porcelain to absorb oil. The interior of the plug body and the electrodes should also be scraped clean of all carbonaceous matter. If the porcelain is scratched or defaced in any manner it should be replaced with a new one. If the plug is apparently in good condition and yet the cylinder refuses to fire, it may be well to substitute the plug with one known to be in good condition, as there may be some minute short circuit in the porcelain that is not apparent upon inspection.

Plugs using mica insulation are very deceptive, as in many cases short circuits exist that cannot be detected by the eye in daylight. A good way to test a suspected mica plug is to lay it on top of the cylinder after dark, taking care not to have the insulated terminal in contact with any metal parts except the high tension current lead. The engine is then run on the other cylinders and the inside of the spark plug watched to see if sparks jump between the insulator and the plug body, instead of between the points. If a short circuit exists it will be easily detected by the minute sparks plainly evident in the darkness. It is sometimes possible to test a plug out in daytime by shading it from the light in some manner, as with a black felt hat. After the spark points have been set correctly, it is well to double up a piece of emery cloth with the abrasive surface on the outside, as shown at Fig. 242, E, and move it back and forth between the plug points a number of

times to brighten them up and to insure that there will be no foreign matter present between them that is apt to short circuit the current. An old tooth-brush and gasoline are the best tools for cleaning a spark plug without taking it entirely apart as stiff brush bristles will remove any oil or material soluble in gasoline. Acetone is a solvent for carbon, and if that material is not baked on too hard it is possible to remove the deposit without scraping it off.

Many cases of ignition trouble have been traced to the use of improper spark plugs or to faulty location of these members. Manufacturers of spark plugs have given the matter of location considerable thought during recent years, and the endeavor is to produce a plug specially designed or adapted for the motor for which it is to be used. The spark plug shell or base is constructed so the spark points will project into the combustion chamber. It is also important to make provision for proper cooling of the spark plug. This last named factor is an important one that is seldom given consideration by owners or repairmen who change the spark plugs without making sure that they are adapted to the motor. To obtain the greatest efficiency from the explosion it is important that the spark points project into the combustion chamber in such a way that they be surrounded with cool fresh gas. If the gap of the plug is located in a recess or pocket, as indicated at Fig. 243, A, dead gas is apt to accumulate about the points, and combustion will be much slower than it would be with the spark plug located as at D. It will be evident that with this construction of the valve cap the spark points project into the induction chamber, permitting the spark to take place in fresh mixture and promote rapid spread of the ignition flame. Another faulty mounting when a plug is located directly in the combustion chamber is shown at C. It will be apparent that with a projection from the plug body having a space around it in which the hot gases may collect, the plug will heat up much quicker than the mounting shown at D in which the heat will be conducted away by the cooling water. A plug that becomes heated will tend to soot up and carbonize much quicker than one in which provisions have been made for proper cooling.

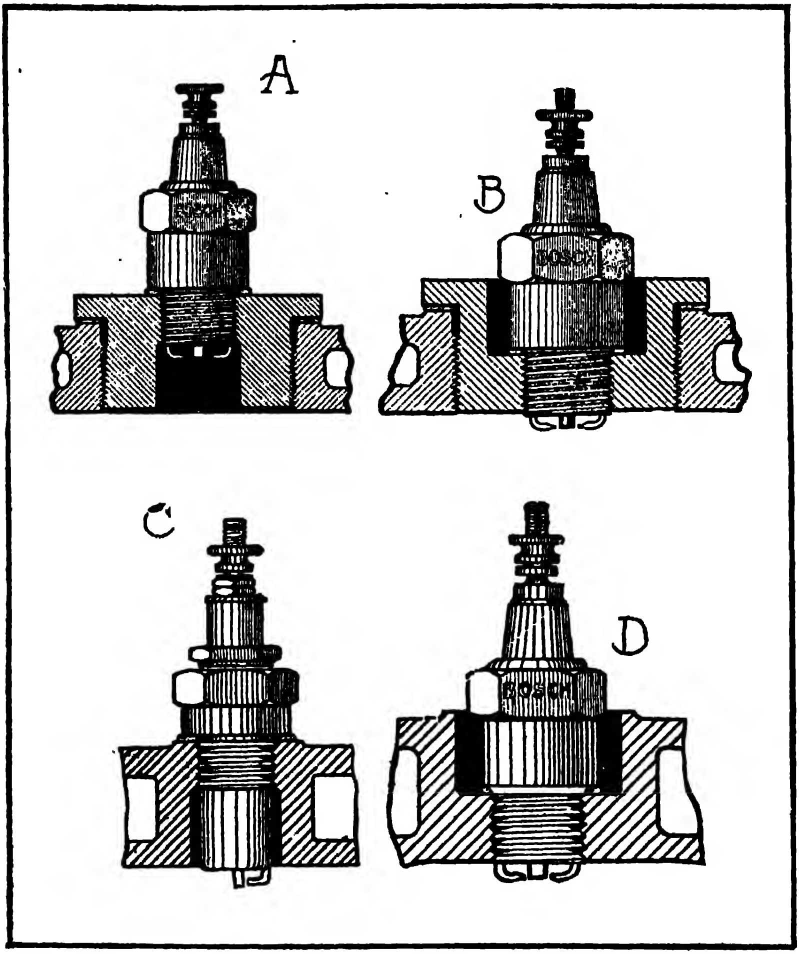


Fig. 243.—Illustrating Proper and Improper Methods of Spark Plug Installation.

Induction Coil Faults.—The high tension induction coil is one part of the ignition system that can seldom be repaired outside of the factory. In the first place it is not possible to reach the interior parts of an induction coil because the windings and condenser are usually imbedded in a hard insulating compound that has been poured into the coil box in a molten condition, and

which becomes as hard as stone when it sets. The only part of an induction coil that is possible to correct is faulty vibrator action, and fortunately the vibrator is about the only part of a well-made coil that demands attention. If the vibrator does not buzz when the circuit is closed at the timer and the wire leading from the timer to the coil unit is found in good condition, the trouble is due to a broken connection inside of the coil box or the contact points do not touch. If the vibrator operates as it should and there is an extremely bright spark between the points and a weakened secondary spark, it is reasonable to assume that the condenser inside of the coil box is ruptured.

If there is a proper vibration or buzz at the vibrator and no secondary spark from the high tension terminal, the trouble is either a broken high tension connection or a short circuited secondary winding. Sometimes a wire inside of a coil is twisted off where it fastens to the terminal screw, due to that member being turned around several revolutions with a pair of pliers. A case of this kind may be fixed by removing the bottom or top of the coil box, as the case may be, and making sure that the connection is resoldered to the terminal post. A punctured winding or short circuited condenser can only be repaired by the coil manufacturer, and in most cases it is cheaper to procure a new coil unit, which is easily removed in modern coils, than to attempt to have the old one repaired.

When a coil unit is suspected of being defective it is easy to ascertain if this is the case by changing it for one of the coil units which is known to be in good condition. If the cylinder which was formerly served by the good coil unit now begins to skip, one may assume that the coil unit is at fault. If the trouble has not been due to other causes, the cylinder that was formerly at fault will begin to operate as it should as soon as the spark plug is connected to the good coil unit which has been substituted for the one thought to be defective.

Adjusting Coil Vibrators.—The repairman who understands the vibrating spark coil is the exception rather than the rule. Many are able to adjust a vibrator, but do not know how to locate troubles, or to remove the exposed component such as the bridge,

vibrating spring, etc., and reassemble the parts correctly. If the vibrator buzzes weakly when contact is made at the timer, the first thing to do is to test the battery to make sure that there is sufficient current available to operate the vibrator, then the contact points should be examined to see that they are clean and smooth. Various defective conditions are shown at Fig. 244, A; any one of these will interfere with correct contact and with proper vi-

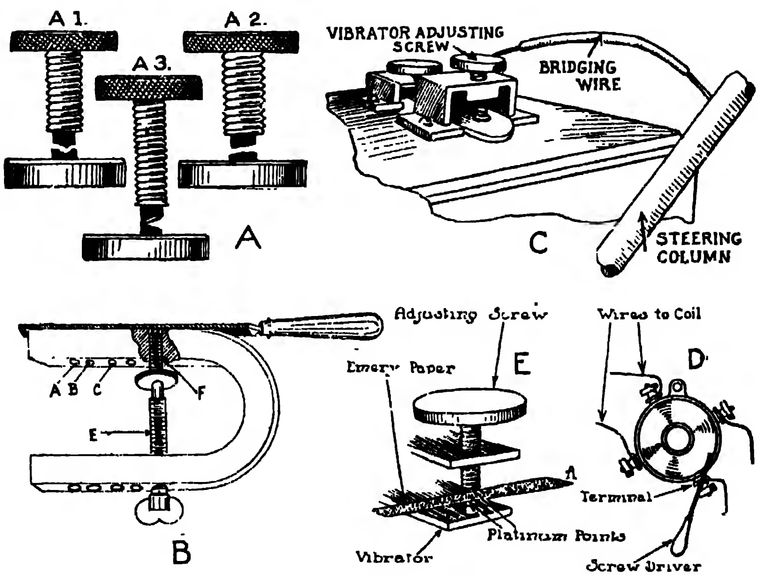


Fig. 244.—Care and Adjustment of Vibrator Contact Points Outlined.

brator action. At A-1 a pit has been burnt in the lower point and a projection has been built up on the upper one. At A-2 the points have been cleaned with a file which has been inserted at an angle so the contact members do not have a true flat surface. At A-3 a point has been built up on one side of the contact of both vibrator springs and contact screw points. As these contact points are of platinum it is important to remove as little of that valuable material (which is now worth more than gold) as possible.

For this reason it will be desirable for a repairman working on cars using vibrator coils to provide himself with the simple fixture shown at Fig. 244, B, which insures that the points will be dressed true without removing much material. The fixture is a simple U-shaped piece of hardened steel having a series of holes, A, B, C, drilled into it of such size as will permit the insertion of the most commonly used sizes of vibrator adjusting screws. These are not threaded, the screw F being a free fit in the hole corresponding to the outside diameter of the thread. A feed screw E may be interposed under the adjusting screw in order to feed it up against the smooth file used to clean off the roughness. This screw may be shifted into any one of the tapped poles under the holes A, B and C for feeding different sized contact screws.

The conventional vibrator is shown at Fig. 244, C, and another form at Fig. 245. It will be noticed that this consists of a vibrator spring or armature carrying one contact point and a bridge member over it carrying another contact which is set into a knurled head adjusting screw in that at Fig. 244, C. The smaller bridge holds the vibrator spring and is also provided with a knurled screw so the vibrator spring tension may be adjusted. Directly under the vibrator is the iron core which attracts it to break the contact between the points. The farther away the vibrator is from the core the more current will be needed to actuate the vibrator. The spring tension should be sufficient, so that the trembler will vibrate fast enough to produce a pronounced buzzing sound. If the vibrator spring lacks elasticity, too much curr nt will be consumed which is an important item if the current for ignition is derived from a dry cell battery. In adjusting the coil vibrator it is not necessary to turn the motor over to establish contact as the tuning up may be readily performed on most coils by connecting a wire to the steering post as shown at C, and touching the knurled head of the adjusting screw or the bridge carrying it with the other end of the wire. It is necessary, of course, to have the switch on the coil in the "on" position. Another method of accomplishing this is to short circuit the timer with a screw driver as shown at B, which is used to bridge the wire terminal and the aluminum timer case. In this way each of the vibrators may be made to buzz

in turn. If the points are not too badly burnt it is possible to clean them with a piece of very fine emery cloth as shown at Fig. 244, B, without removing either vibrator or contact screw from the top of the coil. Where battery current is used it is well to test the current consumption of the coil from time to time as the vibrators are adjusted. It is possible to have a coil draw twice as much as needed if the vibrator spring tension is too great. The

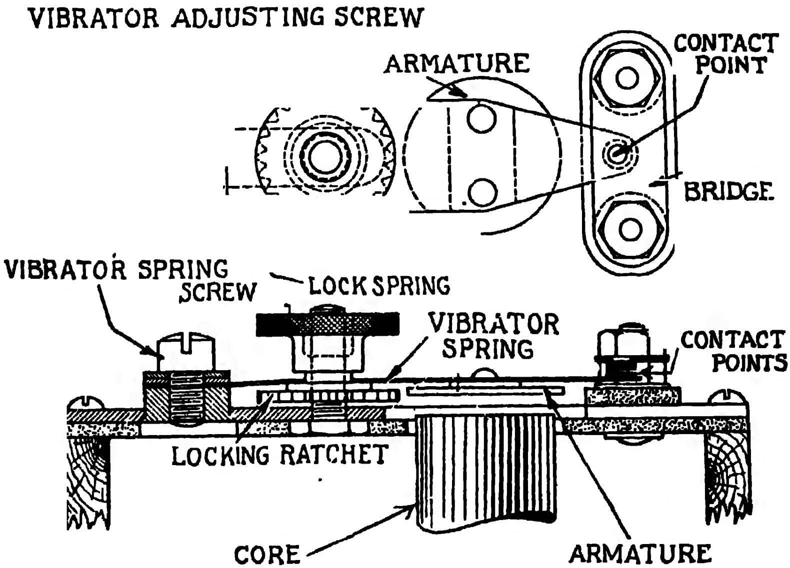


Fig. 245.—Construction of Typical Coil Vibrator.

current consumption will vary from .5 to 2.2 amperes, a fair average being about 1 ampere. The usual primary voltage needed is 5 or 6, and the trembler vibrations will vary from 100 to 400 per second. If the vibrator tends to stick, the core should be filed off as well as the undersurface of the vibrator to remove any rust that may be present between the surfaces. A projecting core wire sometimes interferes with proper vibrator action. Make sure the top of the core is smooth and bright.

Low Tension Ignition Systems.—The low tension ignition system in which a spark is produced in the cylinder between moving electrodes is seldom used at the present time in automobile engines except those of old models. The complete wiring diagram of the low tension system used on the Locomobile cars for a time is shown at Fig. 246, A, while the actuating mechanism and the

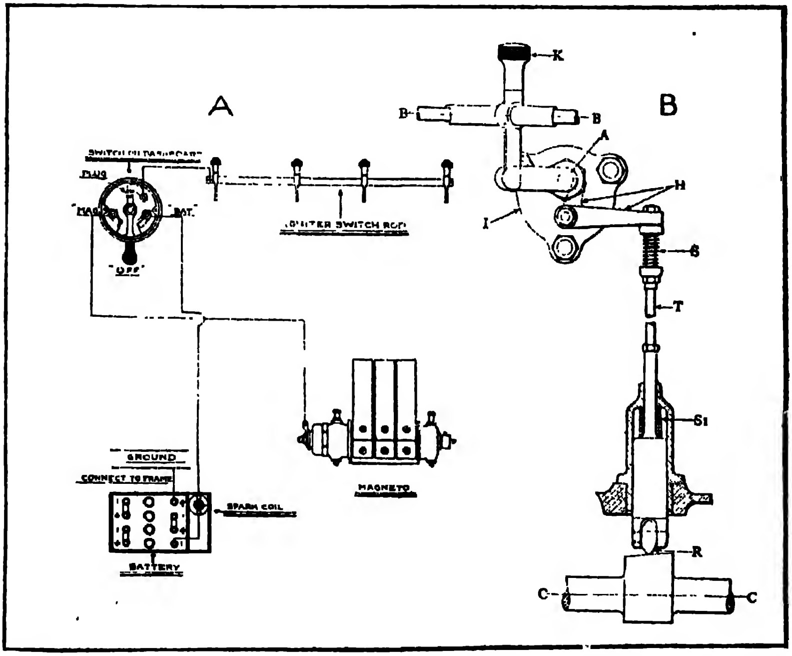


Fig. 246.—The Locomobile Low Tension Ignition System and Igniter Used for Producing Spark in the Cylinder.

igniter plate construction is shown at 246, B. It will be observed that the low tension is a very simple one electrically, but that considerable mechanism is necessary to operate the make and break devices in the cylinders. In the wiring diagram it will be apparent that two sources of ignition current are available, one a low tension magneto for regulating ignition, the other a storage battery in event of the low tension magneto failing to deliver current. One wire runs from the magneto to one side of the switch on the

dash-board. Another wire runs from the spark coil, which is placed in series with a storage battery, to the other side of the switch. From the top of the switch a wire runs to the igniter switch rod or busbar which delivers the current to the four igniter plates, one in each combustion chamber. The igniter plate is an approximately triangular member I attached to the combustion chamber wall by three bolts. It carries an insulated contact member A which is fixed, and an oscillating contact member H which is worked by a lever outside of the cylinder which is actuated by a tappet rod T, lifted by the cam C. A spark takes place between the contact points when the hammer member H breaks contact with the anvil member A. The break takes place when the roller R drops off of the cam profile. This can be timed to occur when desired by suitable regulation means on the tappet rod T. The switch handle K which joins the busbar B to the switch member projecting from A, is necessary to interrupt the igniters in order to locate a cylinder that is misfiring.

About the only thing that can occur is fouling of the contact points by carbon deposits and excessive mechanical depreciation of the actuating mechanism. Either of these troubles is easily determined on inspection and the remedy is obvious.

Trouble is sometimes experienced with the low tension magneto, which is shown in section at Fig. 247. The form shown uses plain bearings and as these require considerable lubricant it is possible for the collecting brushes or armature winding to become oil soaked which interferes with proper delivery of current. It is also important to time the low tension magneto so that the contact points of the igniter plate I will separate when the armature of the magneto has attained its position of maximum current generation. This will be considered in detail in connection with the high tension magneto as will other magneto troubles, so it is not necessary to consider them at this time. It is important that the contact brush shown bearing against the side of the armature and the contact member A, be making a positive connection with the parts they are intended to bear against. Failure of the low tension magneto to deliver current is usually due to poor contact at these points which may be produced by particles of foreign matter or

which may result if the springs maintaining the parts in contact have lost their elasticity. Generally the trouble is gummed oil which is easily removed with gasoline. Sometimes the current delivered by the armature short circuits because of a cracked or oil soaked insulator which carries the contact rod C.

Magnetic Spark Plug Systems.—Other low tension ignition systems have been devised though they have never received wide

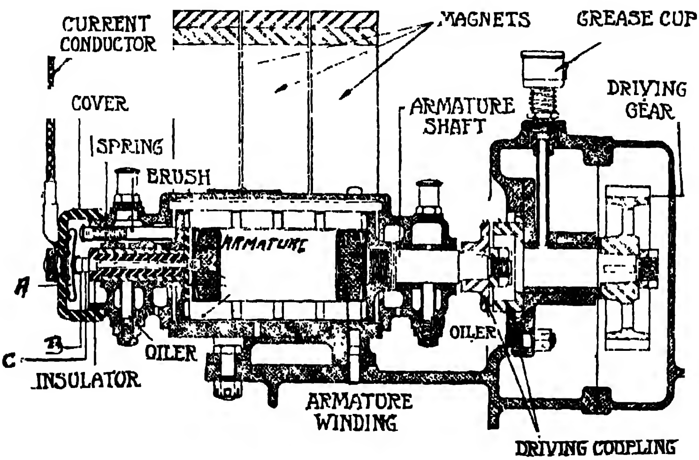


Fig. 247.—Magneto Used with Locomobile Low Tension Ignition System.

application in which the moving mechanism needed to operate the igniter plates from the camshaft have been replaced with magnetically operated spark plugs, the leading example of which is the Bosch shown at Fig. 248, A. This consists of three main parts, a supporting member which screws into the spark plug hole in the combustion chamber, an electro-magnet and oscillating mechanism. The electro-magnet contains a coil of wire D, and is protected by a cover B, and iron outer shell A. A cylinder H which is threaded at its lower end projects into the coil. A collar K forms the base of the magnet. The oscillating mechanism consists of a pole piece E, a horse-shoe shaped spring G, and an armature F. The

lower part of the pole piece is provided with threads to fit the hollow cylinder H, and is formed externally to be retained in the support K by a retaining nut or collar L. The supporting member has the upper half of hexagonal form the same as any spark plug body and is threaded to fit the spark plug aperture. A steatite insulating member J in connection with the packing gasket insures against loss of compression or explosive pressure.

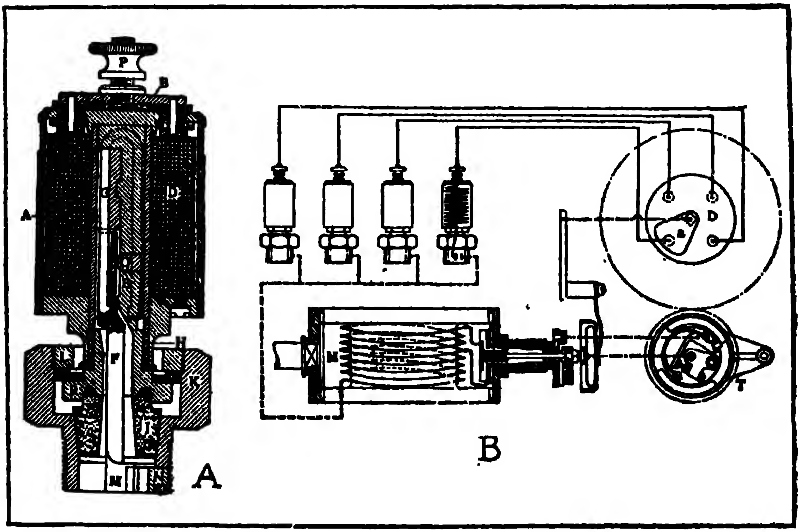


Fig. 248.—The Construction and Application of the Bosch Magnetic Plug.

The operation of the plug is very simple, as when the terminal P is connected to the source of current when the electricity passes through the coil it magnetizes the core E, which attracts the armature F, pivoted on a knife edge extending from E to the right, this separating the contact points M and N and producing a spark. A brass plug O is inserted in the core E so the armature will not stick to the pole piece due to magnetism. A spring G tends to keep the points M and N in contact. The point N is attached to the spark plug body and is V shaped, the other point on the armature being formed to fit into the V portion of M.

The complete ignition system is shown in diagram form at Fig. 248, B, and is very much the same as the wiring for a high tension magneto using jump spark plugs. In addition to the timer or contact breaker which is of the usual form, the magneto must include a distributing device which will allow the circuit to flow to the plug in the cylinder about to fire a charge. The distributor consists of four contact points carried by a body member of insulating material and a rotary distributor arm that makes contact with the different contact points in turn according to the firing order of the engine. The principal trouble apt to occur with the magnetic plug is short circuiting due to carbon deposits or accumulations of oil which will interfere with prompt action of the oscillating armature F. If the spring G breaks, the operation of the plug will be erratic and the engine will misfire. This system has received but limited application on automobile engines, but has been used to some extent in marine engine work so the repairman should, at least, be familiar with its principle of operation in order to have a reasonably complete knowledge of electrical ignition methods.

Wiring Troubles and Electrostatic Effects.—The principal troubles that are apt to occur in the wiring systems are evident on inspection, these consisting usually of a break in the conductor, which may sometimes be concealed by perfect insulation covering; wearing away of the insulation due to abrasion between the wire and some metal portion of the car which eventually results in a short circuit and the wiring becoming oil soaked and failing to properly carry the charge of current which leaks through the defective insulation. The wiring of a complete dual ignition system in which two radically different methods of ignition are used is shown at Fig. 249. One system consists of a set of low tension igniter plates mechanically operated from a suitable camshaft, the other method, which is independent, has high tension ignition plugs operated through a timer of the usual form. At the present time where dual ignition systems are provided the usual practice is to use two high tension systems, one of which will derive its current from a battery and coil, the other which will receive the energy of a high tension magneto. A typical double system

adapted for six cylinder engine ignition is shown at Fig. 250. In this two spark plugs are carried in each cylinder, one over the intake, the other over the exhaust valve. A battery timer is mounted close to the dash from which six primary wires go to the individual coil units of the coil box. High tension wires come

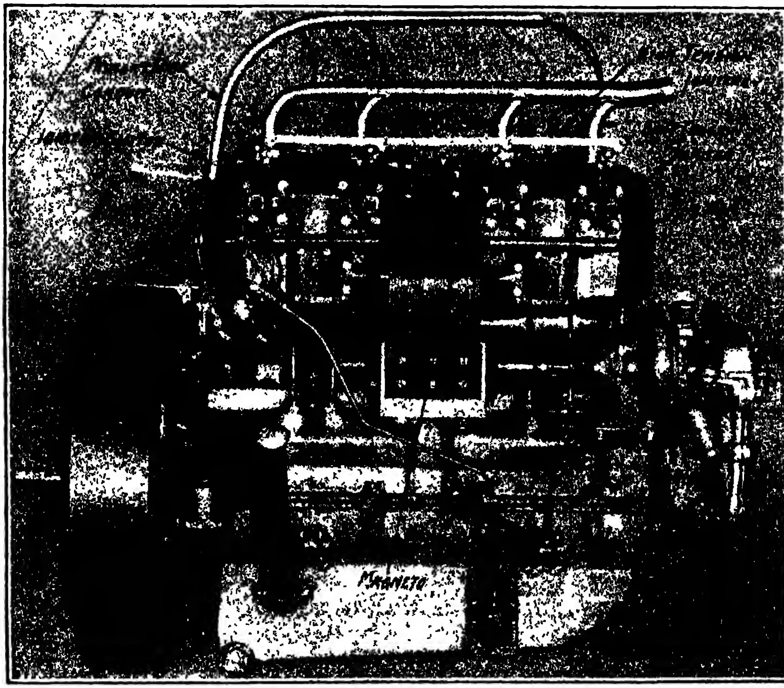


Fig. 249.—Side View of Engine Used on Early Columbia Automobile Having Both High and Low Tension Ignition System.

from the bottom of the coil to one set of spark plugs. Another set of high tension wires extends from the magneto distributor to the remaining set of spark plugs.

It will be apparent that in both of the systems shown that considerable care is taken to have the wiring carried in an orderly manner and kept out of contact with the metal portions of the cylinder by suitable insulating blocks, usually made of fibre, as at Fig. 250, or in a fiber-lined metallic conduit, as shown at Fig. 249.

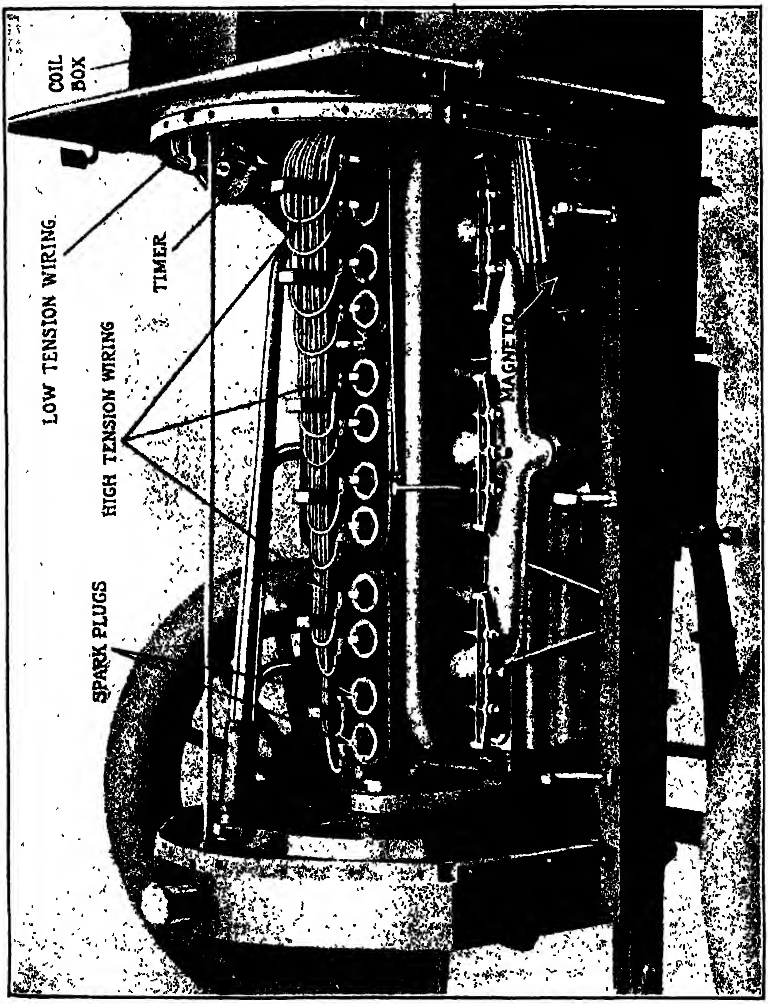
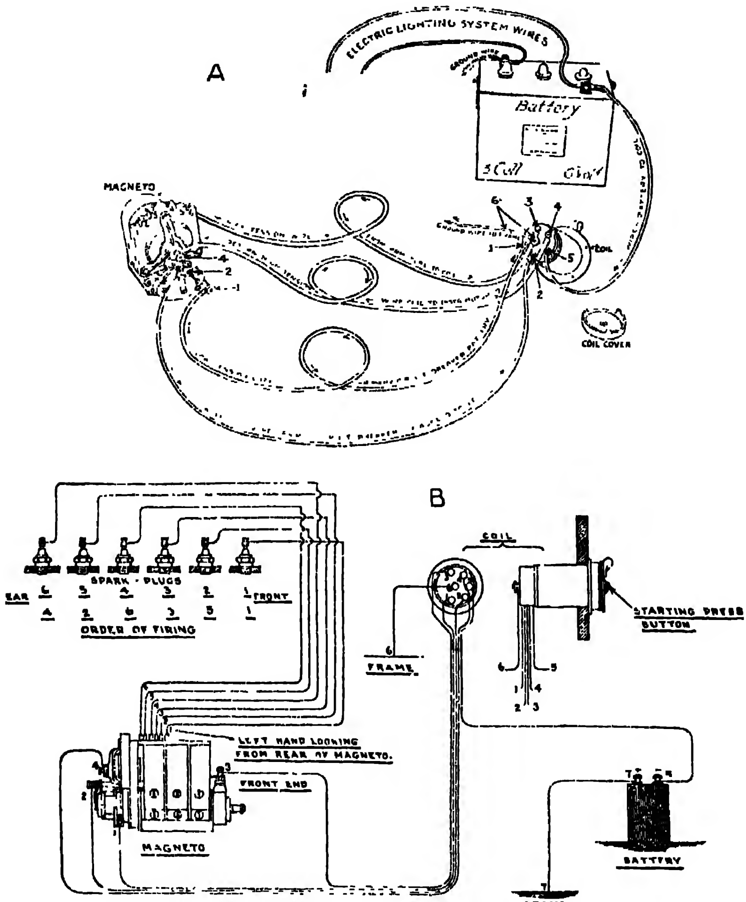


Fig. 250.—Top View of Stevens Duryea Power Plant, Showing Wiring and Other Components of Double Ignition System.



WIRING DIAGRAM, "38" AND "48" LOCOMOBILE

Fig. 251.—Wiring Diagram of Locomobile High Tension Ignition.

A typical double ignition system which has been used on some models of the Locomobile is clearly shown at Fig. 251. The method of running the wires for the primary circuit is very clearly outlined at A. The complete wiring diagram showing the high tension leads going from the magneto distributor to the spark plugs is shown at B. With a system of this kind the current may be de-

rived from a battery which is timed by a primary circuit breaker attached to the magneto contact breaker box and sent through a single unit coil secured to the dash. The secondary current from the coil is led to the center of the magneto distributor, which serves the dual purpose of directing the high tension current from either the magneto armature or the induction coil to the spark plugs in the proper firing order. The usual method of housing the secondary cables in a conduit of insulating material so that there will be no liability of short circuiting due to oil accumulations or to contact with metal parts is so clearly shown at Fig. 251 that further description is unnecessary.

The repairman does not generally recognize the fact that the manner in which the high tension cables are led from a magneto or spark coil to the spark plugs is sometimes the cause of misfiring and ignition irregularities which are hard to locate. A spark may sometimes occur in a cylinder in which the piston is going down on its suction stroke which is not due to defective insulation of the wires or to short circuiting, but to an electrostatic action between one wire and a neighboring one through which no current is flowing. Endeavor should always be made to keep the secondary cables as short as possible, as in some cases if a conductor is too long the tendency is toward an unreliable spark. Some ignition experts condemn the practice of running the secondary wires close together in a fiber-lined conduit and recommend the use of fiber cleats secured to supports extending from the engine and provided with grooves that will hold the cables some distance apart.

When individual unit coils are used a condition that often puzzles those who have had no previous experience with it is what is known among old-time repairmen as "bucking," this usually being evidenced on engines of the four or six cylinder forms. The symptom is the same as a premature explosion in some one of the cylinders, this having a tendency to cause the engine to come to an abrupt stop. One is often led to believe that a short circuit exists at one of the timer wires which allows a contact being made at the wrong time, producing a spark in the cylinder about to fire before the gas is fully compressed or the piston has reached top center. This is due to an inductive interference between one induc-

tion coil and a neighboring one. It is known that when the primary coil becomes energized in any unit the core becomes a magnet, and as is common with all bar magnets, lines of force are given out which run from the north to the south poles and which induce a current in the secondary winding of the transformer coil. If this magnetic influence does not stray from its proper confines no trouble will be experienced. If a portion of this magnetic field strays

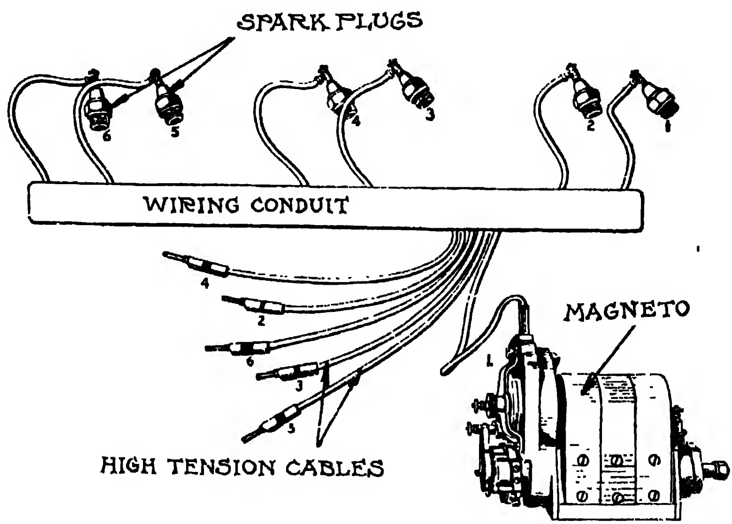


Fig. 252.—Method of Carrying High Tension Cables in Conduit.

over into a neighboring coil unit enough voltage may be induced in the secondary winding of the latter to produce a weak spark at a spark plug connected with a coil which rightly should remain inactible. This condition is more noted with old-style induction coils than with modern ones, and usually results when the motor is running slowly. The trouble has been eliminated in many of the later forms of multiple unit coils by providing anti-induction shields between the units. These are merely metallic strips in which the energies from the stray magnetic force is dissipated in

the form of eddy currents instead of cutting wire layers of adjacent units. If this trouble is experienced and none of the common faults are found to exist, such as carbon deposits and rough edges in the interior of the combustion chamber or long, thin spark plug points which remain incandescent and retain heat from a previous explosion, one may suspect trouble in the multiple unit

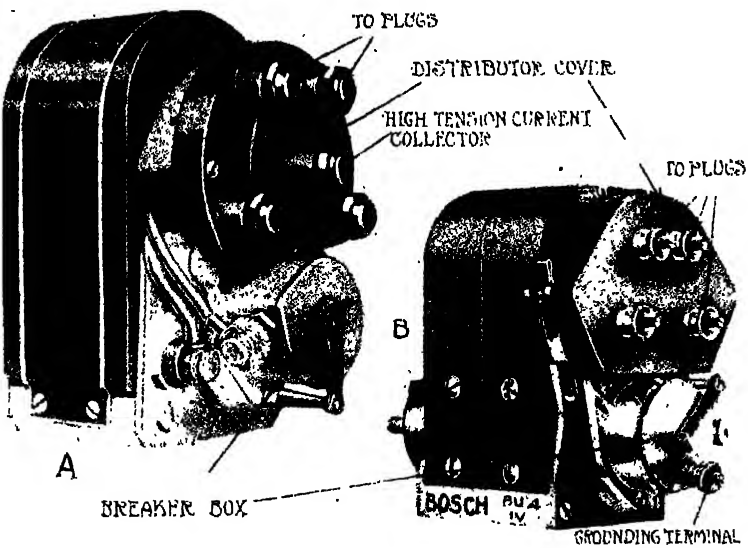


Fig. 253.—External Views of Typical Magneto Ignition Devices. A.—The Remy Magneto. B.—The Bosch Du 4, a True High Tension Type.

coil. It has been cured at times by inserting thin strips of sheet iron between the coil units. The most frequent cause of "bucking" is defective insulation of the secondary wires, which allows the current to jump from one cable to another. This is sometimes found to be the case when all cables are passed closely together through a common tubular conduit, and is not apt to result when wires are carried apart in cleats.

Troubles with High Tension Magneto.—Before describing the various high tension magneto troubles it may be well to review briefly the construction of typical magneto forms in order that the

repairman may become familiar with the principal types. High tension magnetos may be either one of two general forms, as shown at Fig. 253, it being practically impossible to distinguish between them from external appearances unless carefully examined. The magneto shown at A is a transformer coil type, i.e., it generates a current of low voltage, which must be intensified by a separate coil of the non-vibrator form, the high tension coil current being brought to a central terminal on the distributor and from that point led to the various spark plugs by the rotary distributing brush. The true high tension magneto, which is shown at B, is a complete ignition system in itself, and does not depend on any appliances other than the spark plugs in the cylinders and a small grounding switch. A high tension current is delivered from the armature directly to the distributing member and no separate transformer coil is needed unless the magneto is used with a dual system. The parts that demand the most frequent inspection in a magneto are the more accessible ones, these being the breaker box, which houses the contact points, and the distributor, which is utilized to commutate the secondary current.

The construction of a Splitdorf magneto is clearly shown at Fig. 254. The longitudinal sectional view shows clearly the component parts of the device. The armature is wound to produce only low tension current, so the magneto must be used in connection with a separate transformer coil. A sectional view of a true high tension magneto, the Eisemann, is shown at Fig. 255. This differs from that at Fig. 254 in that it employs a double-wound armature, which delivers a current of high potential to the distributor. The spark time is advanced and retarded on most magnetos by rocking the contact breaker back and forth by a suitable mechanical connection with the spark lever on the steering wheel. In the Eisemann magneto outlined an automatic spark control or advancing mechanism, which increases the lead of the spark as the engine speed increases, is included. The operation of this automatic timer is very much the same as that of the Delco automatic spark advance, previously described. The governor weights are carried by a sleeve or quill mounted on an extension of the armature shaft, which has a rectangular block sliding within

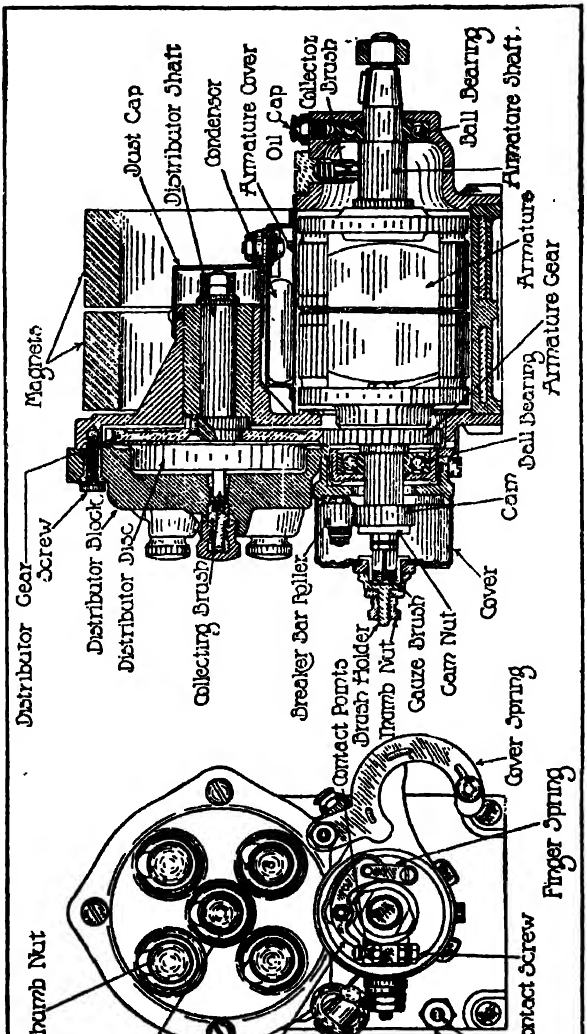


Fig. 254.—View Showing Construction of Splitdorf Magneto.

it. This block is threaded for receiving a spirally cut shaft, which is driven by direct connection with the engine through some form of gearing. The governor weights are attached to the sliding block by means of links, and as the shaft is revolved the weights tend to spread apart, and as they do the block is made to slide in the quill. In so moving it travels along the threaded shaft, which results in slightly rocking the block. As the block oscillates it car-

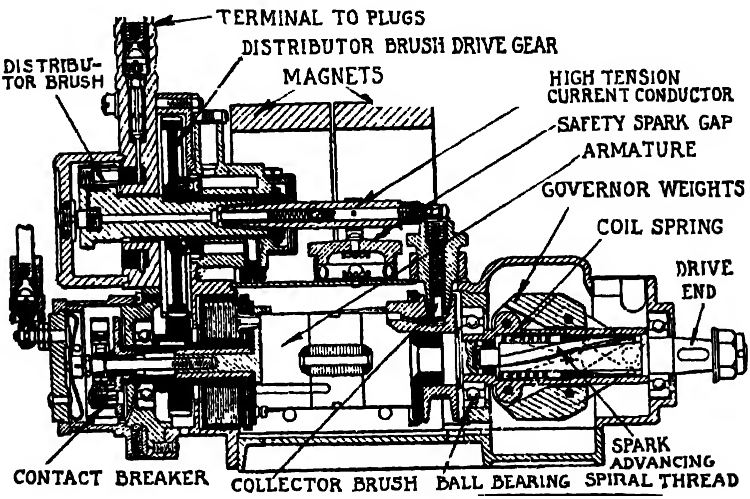


Fig. 255.—The Eisemann High Tension Magneto with Automatic Spark Advance.

ries the quill, in which it works, forward slightly and also the armature shaft to which the quill is fixed. The armature is thus advanced and also the commutator, which is attached to the front end of the armature shaft. As the speed increases the governor weights fly farther out and advance the time of ignition. When the speed diminishes the weights tend to close up, this being assisted by the action of a coil spring, against which the governor weights work at all times. An automatic spark advance may be obtained from 18-57 degrees with this construction.

One of the most popular of high tension magnetos is shown in section at Fig. 256. This is of Bosch manufacture, and is known as the D 4. The magnetic field is produced by the horseshoe mag-

nets A, of compound form, which are attached to the pole pieces, the space between forming the armature tunnel, in which the double-wound armature B revolves. This carries a condenser, which turns with it, and also the rotating portions of the contact breaker. The armature is supported on ball bearings in order that it rotate freely. A small spur pinion, Q, is attached to the armature and

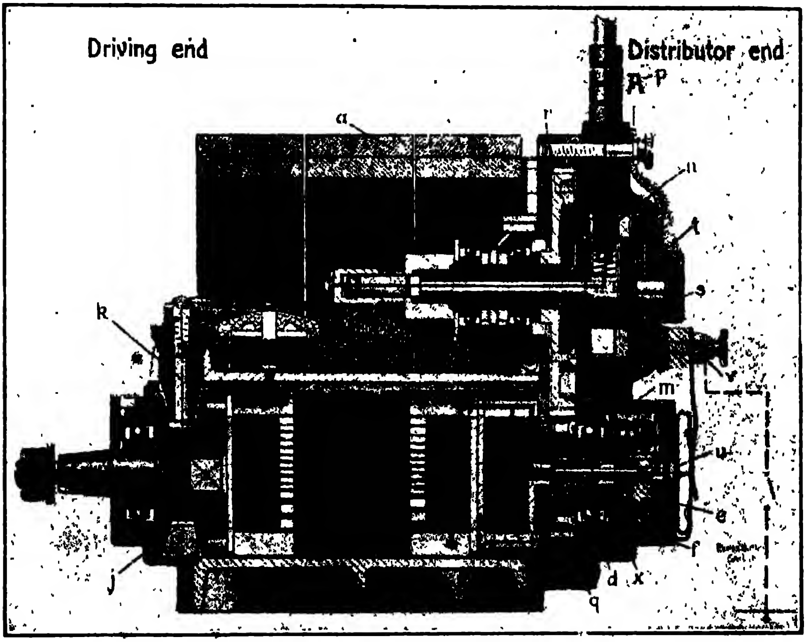


Fig. 256.—Sectional View of Bosch High Tension Magneto.

serves to revolve a larger spur gear, R, which drives the distributor. The current generated in the armature winding is collected by the brush K, which bears against the insulator collector ring J which is mounted on an ebonite spool to prevent current leakage. From the brush K the current is conveyed by the connector L tc another brush, which is in contact with the current conveying pencil N, which delivers the electrical energy to the rotating distribu tor brush N. The rotating parts of the distributor are mounted oı ball bearings in order to eliminate troubles due to bearing depre

ciation. A safety spark gap M is attached to the dust cover Z, the function of this device being to act as a safety valve for the grounding of any excess current, such as might be produced if the magneto was run without having the distributor connected with the spark plug.

The arrangement of the distributor and the contact breaker mechanism is very clearly outlined at Fig. 257. The distributor, which is the upper portion, is employed in commutating the secondary or high tension current only. The contact breaker or lower assembly breaks the primary circuit. One end of the coarse winding of the magneto armature is led to the fixed contact member E by means of the screw plug D, which serves to retain the contact breaker assembly to the armature shaft. The contact breaker casing, which is capable of oscillation but not of rotating, carries the fiber cam rollers W. As the portion F of the contact breaker revolves the toe portion of the bell crank lever G is pushed up and in by the cam roller, this separating the contact point H from the fixed contact point carried by member E. Every time that the contact points separate a current of high potential is sent through the connector member L and the conducting pencil N to the distributing brush N. When the contact points separate this distributing brush should be bearing against one of the segments carried by the distributor block O, this being in turn connected to sockets at the top of the block in which the plug terminals P fit. The bell crank lever G is kept pressed out by the flat spring I, which keeps the contact points together except at such times as they are separated by the cam rollers Y. It will be seen by reference to Fig. 256 that as the distributor brush N is driven by positive spur gearing that it must turn in an opposite direction to the armature and at just half the armature speed on account of the distributor gear R being twice the size of the pinion Q. The brush N is therefore revolved in definite timed relation with a contact breaker assembly F and the armature B. It will take two revolutions of the armature to produce one revolution of the brush N. This means that the contact points separate each revolution of the armature and that the brush N makes contact with two of the distributor segments for each turn of the armature.

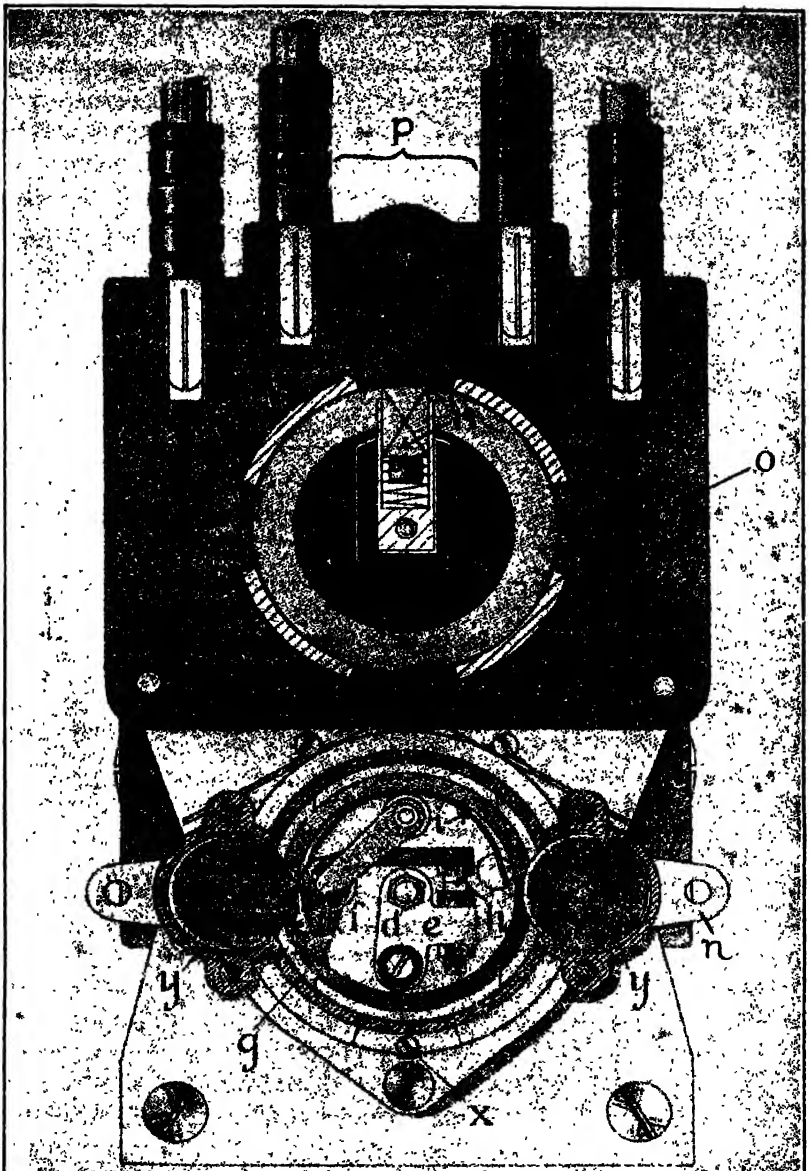


Fig. 257.—Front View of Bosch Magneto Showing Arrangement of Contact Breaker and Distributor Mechanism.

Another form of Bosch magneto which is practically the same in general principles as that just described, except for slight differences in the contact breaker and distributor, is shown at Fig 258. This is a smaller device, using two single horseshoe magnets, and is intended for small engines up to 30 H.P. The bigger magneto, with its three compound magnets, is more powerful and will

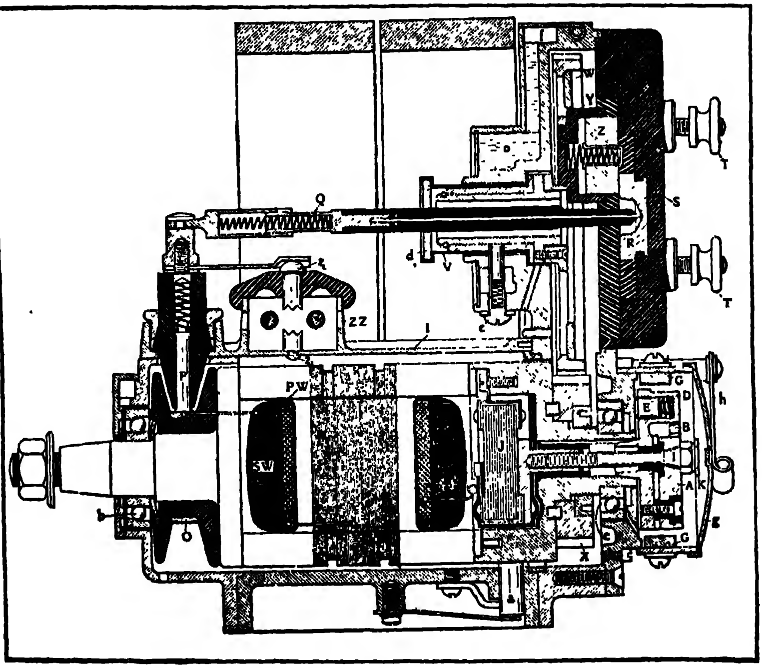


Fig. 258.—Sectional View of Bosch D U-4 Magneto.

produce a hotter spark, such as is necessary to ignite the volume of gas in large cylinders. The Bosch DU-4 magneto contact breaker and distributor are clearly illustrated at A, Fig. 261.

All magnetos do not have rotating windings, three makes, the K-W, Splitdorf Dixie and the Remy utilize a fixed winding and rotary inductor, substantially as shown at top of Fig. 259. The inductor pieces are used to conduct the lines of magnetic energy through the winding and produce the current by cutting the turns

of wire. In the armature shown in the lower portion of Fig. 259 the windings revolve in the magnetic field and generate the current. Another form of magneto which is used on but one make of car, the Ford, but which enjoys a wide distribution, is shown at Fig. 260 in connection with the complete ignition system of the car. Sixteen coils of coarse conductor are carried by a fixed plate,

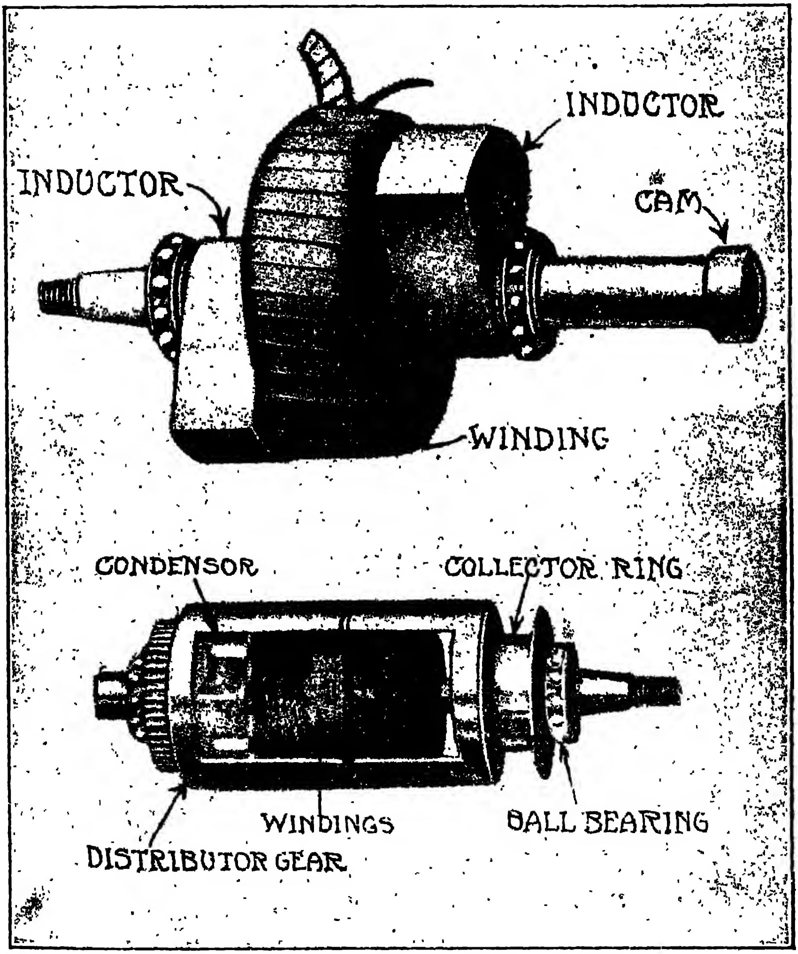


Fig. 259.—Remy Rotary Inductor Using Fixed Windings at Top, Conventional Double Wound Armature with Rotating Windings at Bottom.

which is bolted to the engine crank case. A number of horseshoe magnets, not shown in the illustration, are carried by the ends of the flywheel and revolve in front of the fixed coils, the space between the magnet poles and the cores of the windings being just enough to provide clearance without danger of hitting the magnets. Owing to the large number of magnets and coils employed, a very strong current is obtained, which, while alternating in character, is used in the same way as battery current would be

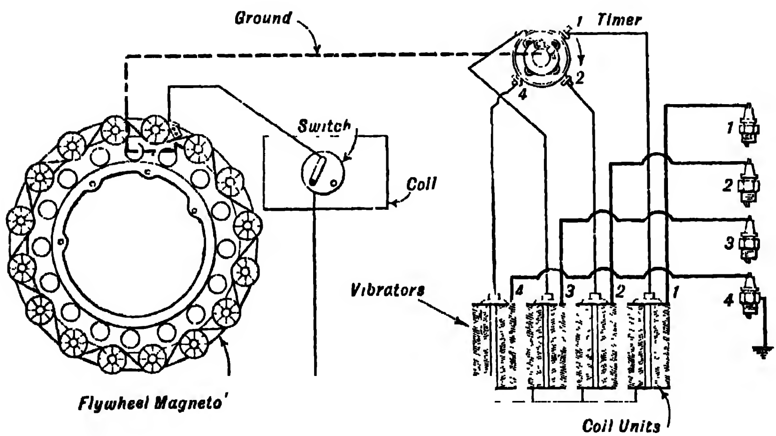


Fig. 260.—Diagram Showing Ford Magneto Ignition System.

through four individual vibrator coils, which are brought into circuit progressively by the rotary contact timer.

The most popular form of magneto, if one can judge by the numbers of manufacturers using it, is the true high tension type with the revolving winding, though the low tension type using transformer coils have also been used to a large extent.

In case of trouble with a magneto the point to be determined, first of all, is whether the fault is with the current generator, if it is a true high tension form or in the plugs, or in the event of a transformer coil being employed, if that member is at fault. In cases where only one cylinder is firing irregularly the fault is very

likely to be with the spark plug in that cylinder. The common troubles of spark plugs and the method of repairing them have been previously described. After the spark plugs have received attention the cables must be tested to make sure that the insulation is not injured in any way or that the metal terminals at the end of the cable do not come in contact with any metal parts of the motor or magneto. If the ignition fails suddenly, one can suspect a short circuit in the grounding cable, which is connected to the nut on the magneto contact breaker and which serves for switching the ignition off. This may be easily ascertained by removing the cable from the magneto and seeing if its removal enables the magneto to run correctly. A spark leaping the gap in the safety de-

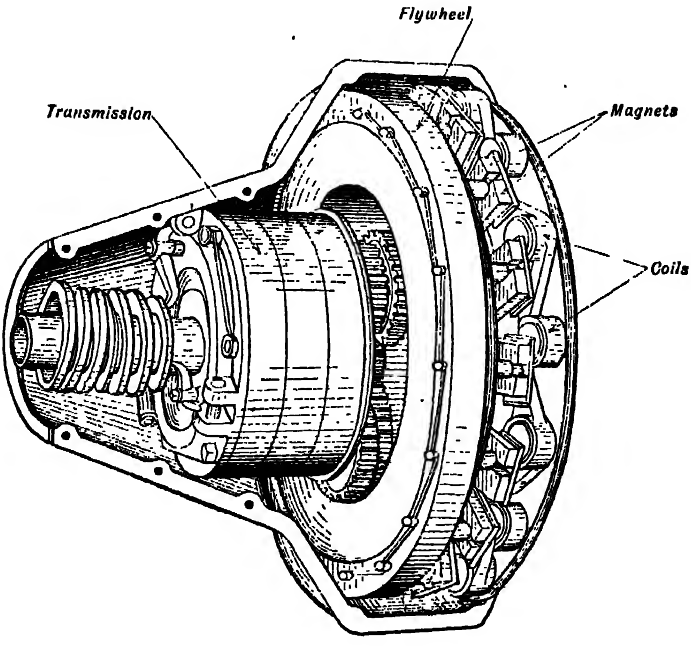


Fig. 260a.—Showing Coils and Magnets that Comprise Ford Magneto and their Relation to the Flywheel and Transmission Gear.

vice indicates a broken wire or one that has become disconnected either from the plug terminal or from the distributor terminal.

If the cables and plugs are in good condition and the engine works irregularly, it is apparent that the trouble is in the magnet if it is an ignition fault. In event of this, the most important thing to do is to make sure of the proper interruption of the primary current. The spring holding the cover of the contact breaker in place should be moved sideways and the brass cover taken off. It is then important to see if the screw D, Fig. 257, is tight. If this is found

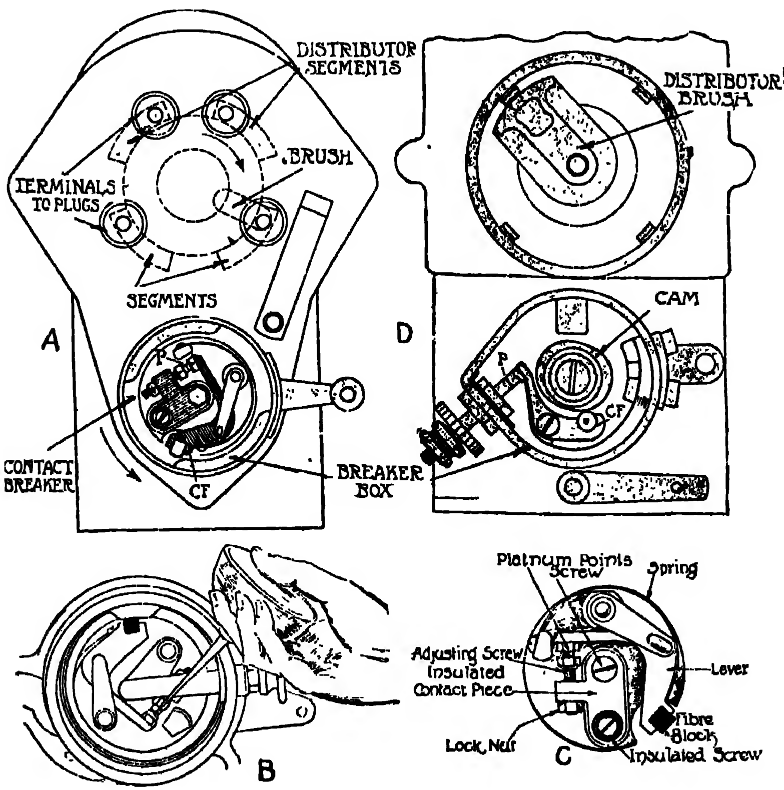


Fig. 261.—Illustrating Methods of Adjusting and Caring for Magneto Contact Breakers.

to be set up properly the next thing is to make sure that the contact breaker points are in contact when the bell crank lever is out of contact with the cam in the sides of the breaker box in the type DU-4 or away from the fiber cam rollers in the type D-4. It is also important that the platinum points are separated by the proper distance, about .5 millimeter, when the lever C F at A, Fig. 261, is in contact with the cam. If the points are too far apart they should be brought nearer together by loosening the lock nut on the adjusting screw shown at C, Fig. 261, and screwing it up to lessen the difference, or to screw it back and open the gap if it is not sufficient. The platinum contact points must also be cleaned, any dirt or oil being easily removed, as shown at Fig. 261, B, by gasoline squirted on them from a small hand oil can. In case the contacts are uneven, pitted or blackened, they must be smoothed with a jeweler's fine cut file. After continued use, if the platinum points have worn down the platinum-pointed screw must be removed. It is also important to make sure that the high tension current collecting brush, K, Fig. 256, is in contact with the collector ring, and that the conducting pencil N makes proper contact with the brush, against which it bears. This high tension collecting brush is indicated as P, and the collector ring as O, in Fig. 258. The interior of the distributor must be clean and free of metallic or carbonaceous matter. The distributing brush must bear positively against the distributor section and the interior of the distributor should be smooth and all contacts clean and bright.

Mention has been previously made of making sure that the screw which keeps the contact breaker assembly in proper relation with the armature shaft is tight, which calls for careful examination. If this screw is loose, the contact breaker assembly will not move in proper timed relation with the armature; in fact, it may not move at all, which will prevent the contact point from separating and which will also result in failure of the ignition. If everything appears to be all right about the magneto, the timing should be verified to make sure that the spark is occurring at the right time in the engine cylinders. It is easy to tell if the magneto is producing a spark of proper intensity by uncoupling a spark plug conductor and holding it a short distance away, not more than

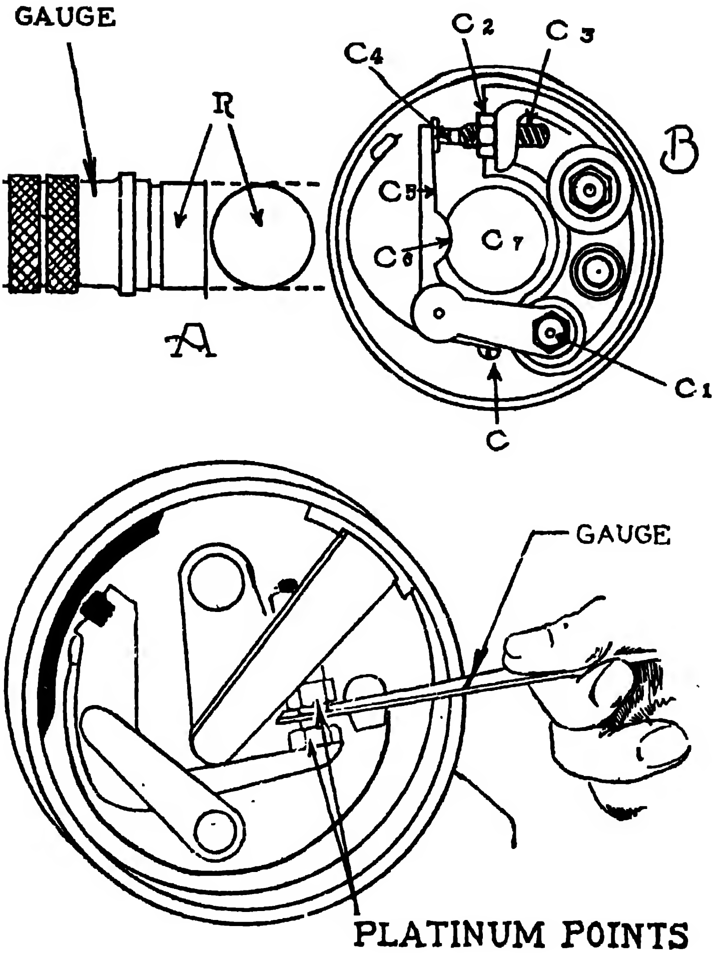


Fig. 262.—Outlining Use of Gauges in Obtaining Correct Setting of Magneto Contact Breaker Points.

⅛″ from the terminal. If a magneto is functioning properly a spark will jump the air gap thus created.

At Fig. 261, D, the contact breaker and distributor construction of the Remy magneto is shown. It will be observed, in this case,

that the contact breaker assembly does not rotate, as in the Bosch, but that a rotating two-point cam is attached to the armature shaft and interrupts the contact between the points P by bearing against the end of the bell crank CF. The instructions given for care of the Bosch magneto apply just as well to this device. Realizing the importance of having the gap between the contact breaker points of the proper amount, the magneto manufacturers furnish gauges which are to be used for testing this gap. That shown at Fig. 262, A, is for use with the Eisemann magneto. With the contact breaker removed, as indicated at B, the contact points C-4 should be together as indicated. When the gauge is inserted in the hole C-7 it will indicate the correct amount the point should be separated. The gauge at Fig. 262, C. is merely a piece of thin sheet steel of the proper thickness which is used as indicated when the points are separated by the bell crank lever riding on the cam block.

Recharging Weak Magnets.—After a high tension magneto has been in use for a time the magnets lose their strength and it is necessary to recharge them in order to restore the magneto to its full efficiency. When magnets are weak the resulting secondary spark will also be weak and the motor will not run regularly, no matter how carefully the device is adjusted. If the motor does run without misfiring it will not develop its full power if the magnets are weak. An electro-magnet designed to operate on 110-volt current is shown at Fig. 263, A. The core is of soft iron, 1″ in diameter and 8½″ long. They are drilled at the bottom for a retaining screw, which is intended to keep them in contact with a base plate of steel 4½″ x 9″. Two blocks of steel 1¾″ x 2″ x 4″ are drilled to receive the cores, and have set screws in the side so they can be clamped tightly against the core to form polepieces. A brass tube about 1/16″ thick at the side, having flanges at each end projecting over to hold fiber insulating plates as shown, may be turned to the dimensions indicated in a lathe or may be made up of sheet stock if desired. The hole through the center of the brass spool is of such size as to permit the core to fit freely in its interior. Besides this equipment, 22 lbs. of No. 20 B. & S. gauge insulated copper wire will be needed. Eleven pounds is wound around each brass tube, winding one coil in one direction and the other the

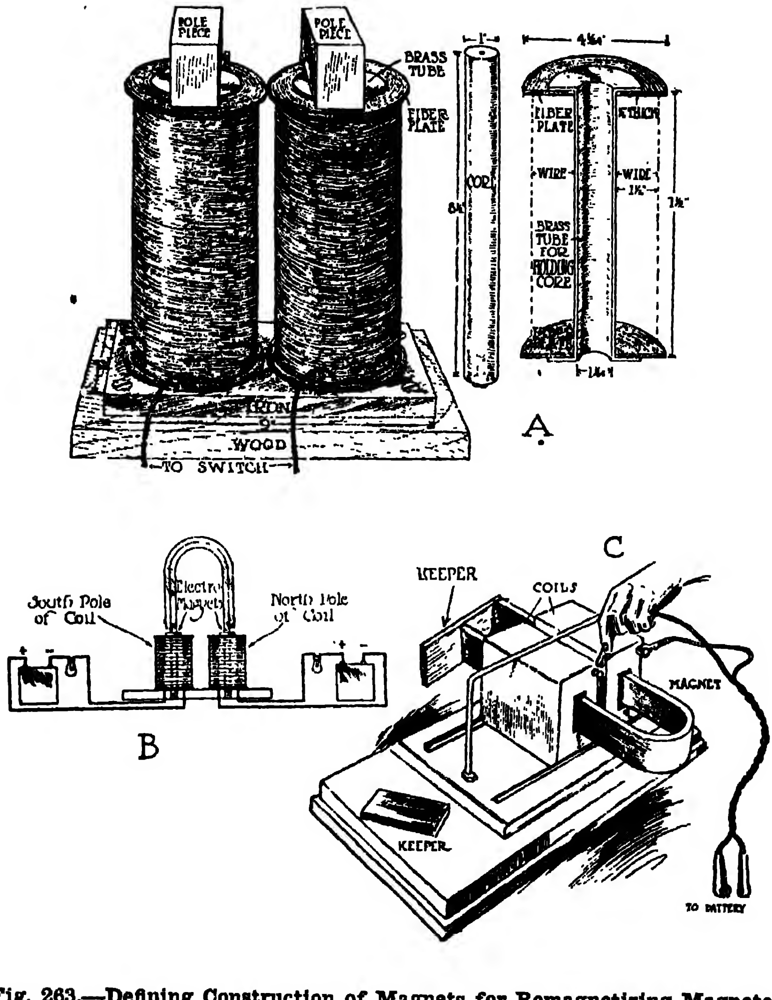


Fig. 263.—Defining Construction of Magnets for Remagnetizing Magneto Field Members.

opposite way. Leave about 6″ of wire when starting to wind the coil in order to make a connection between them. After both coils have been wound shellac them thoroughly and wind insulating tape over the outside. The cores are then fastened to the iron base

plate, the coils are slipped over the cores and the pole pieces attached to keep the coils in place. The view of the completed magnet is clearly shown in the assembly depicted at Fig. 263, A. This can only be used with 110 volts direct current.

Before recharging the generator magnet it is important to test the polarity of the electro-magnet, as the north pole of the magnet to be charged must be brought in contact with the south pole of the electro-magnet and vice versa. It is not difficult to ascertain the polarity by using an ordinary compass or magnetic needle, the marked pole of which will point toward the north. Once the polarity has been determined the poles may be marked in any desired way, usually by stamping the north pole N and the south pole S. Another magnet-charging device, which was described in the Commercial Motor, utilizes storage batteries as a source of magnetizing current. The magnets are composed of soft iron core pieces about 6″ long and 1″ in diameter. The base is constructed of mild steel plate, the cores being fastened to the plates by screws or by turning down the end of the core and threading it to fit the hole in the base plate. Before screwing down the core pieces they are wound with No. 22 gauge insulated wire, the ends being left free. The wires are connected up to a pair of storage batteries, as shown, and the latter are so connected up that the polarity of the soft iron cores are north and south respectively. Enough of the wire is wound on to have coils of about 2″ in diameter. If the core shows signs of overheating, low-voltage lamps should be placed in the circuit to introduce some resistance. The voltage of the lamp to be used depends entirely upon the voltage of the battery used to energize the magnet. It is stated that the magnets will be charged if they are merely placed in contact with the energized cores until they have absorbed sufficient magnetism to enable them to sustain a weight of 10 lbs. after which they are ready to be replaced on the magneto.

The illustration at C, Fig. 263, shows the Seanor garage magnet charging outfit, which is claimed to charge the magnet in one minute. From the exterior view of the device it will be evident that it consists of a base upon which are mounted two solenoid coils carried in square boxes. The magnets to be charged are in-

serted through the center of these coils during the energizing process. In order to accommodate a horseshoe magnet of any spread, one of the coil boxes is mounted so the distance between the two openings is altered if desired. As ordinarily constructed, the windings are wound for 6 volts and 20 amperes. In charging a magnet the ends of the horseshoe are brought up against an iron core of the coil in such position that the magnet is attracted and not repelled by the core. The magnet is then pushed through the apertures in the centers of the coil boxes, taking the place of the iron core, which is slowly pushed out. The current is then connected for merely the length of time required in touching one of the terminals of the wire to the binding post two or three times. A keeper is then laid across the part of the magnet arch which projects beyond the coil boxes, and with the keeper still in place the magnet is replaced on the magneto. It is stated that a freshly charged Tungsten steel magnet of a large magneto will lift in the neighborhood of 20 lbs. as ordinarily energized by the magneto manufacturer. It is stated that with this device the magnet pull can be increased to 30 lbs., which, of course, means a stronger magnetic field when reassembled on the magneto.

Transformer Coil Magneto Systems.—Methods of wiring typical transformer coil magneto systems are shown at Figs. 264 to 266, inclusive. At Fig. 264 all the parts of a system of this nature are clearly shown, and the wiring may be readily traced from the magneto or battery to the coil. It will be apparent that at the bottom of the single unit coil there are four primary terminals and one secondary terminal. A high tension cable runs from the secondary terminal, which is protected by an insulating member to the central distributing terminal on the face of the distributor. The terminal marked "Bat." is attached to the carbon of a 5 dry-cell battery, while the zinc terminal of the series is connected with a terminal marked "Int." and "Bat." From this same terminal a wire runs to the terminal on the side of the contact breaker. The terminal on the face of the contact breaker is coupled to the coil terminal marked "Mag." A terminal on the coil marked "Grd." is attached to the grounding terminal on the magneto contact breaker. With this system, when the switch lever is pushed over

to the side marked "Bat.," the current from the dry cell battery is conveyed to the magneto interrupter, from which it is led to the primary winding of the coil. The secondary current is distributed by means of the magneto distributor to the spark plugs in proper firing order. When the switch lever is shifted to the other side

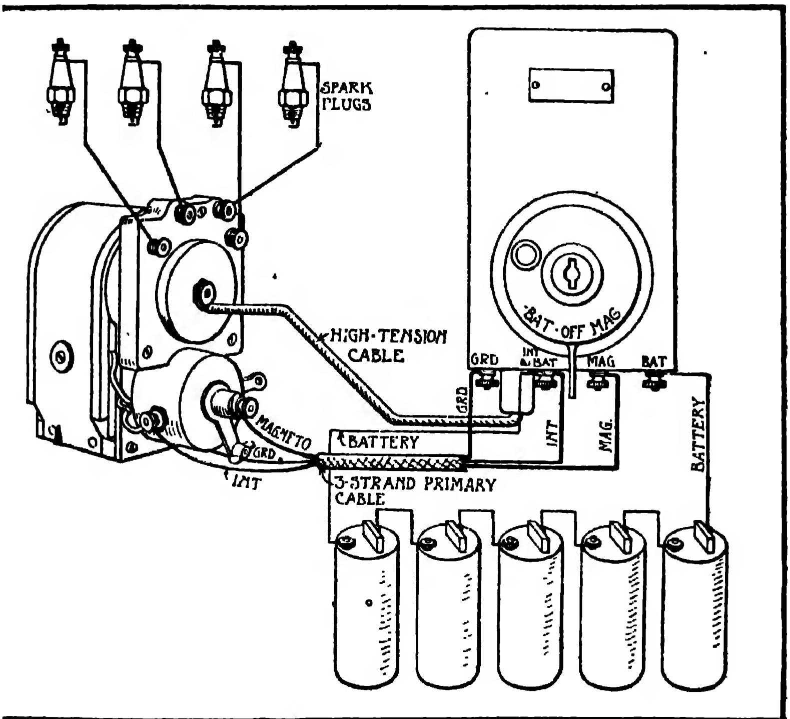


Fig. 264.—Typical Transformer Coil Magneto Ignition System for Four Cylinder Engines.

of the switch, which is marked "Mag.," the current for ignition is obtained from the magneto armature instead of the battery.

Two of the Splitdorf ignition systems are shown at Fig. 265, that at A being used in connection with a round type dash coil, while that at B is employed with a square type dash coil. The coil at A has but six terminals, that at B has seven terminals. In

the coil at A the center terminal is used for the high tension current and is connected to the central terminal of the magneto distributor. Terminal A of the coil runs to terminal A on the magneto contact breaker face. The wire marked "2" runs to the terminal on the side of the contact breaker. A wire joins terminal "3" on the coil with the grounding terminal "3" on the magneto.

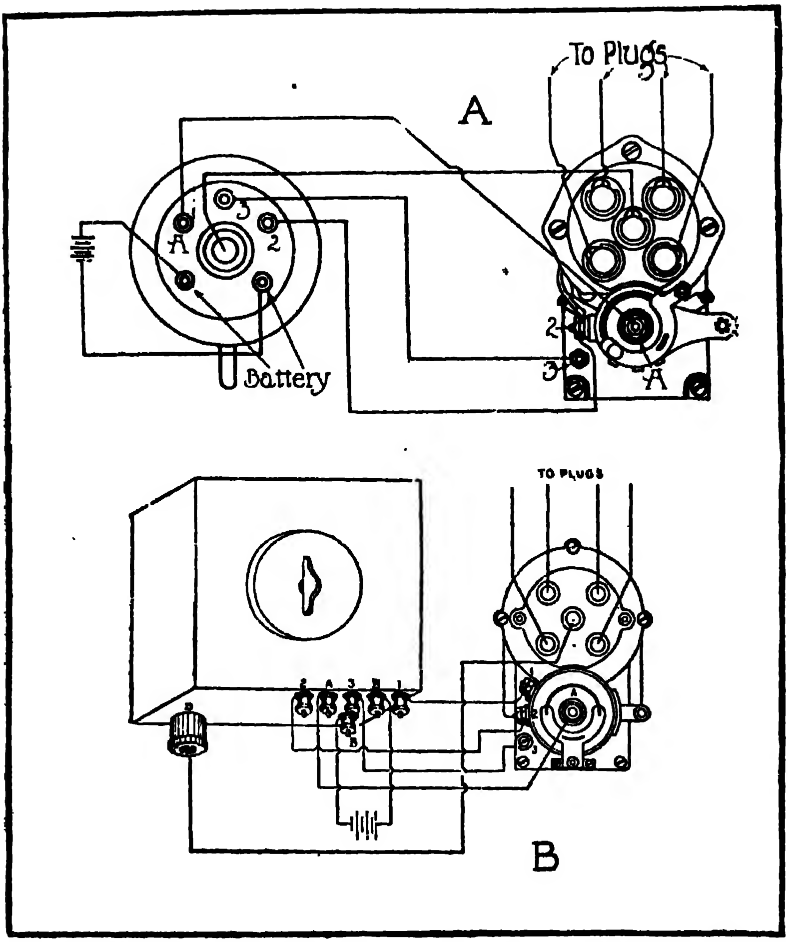


Fig. 265.—Wiring Diagrams, Showing Application of Splitdorf Transformer Coil Magneto System.

The two remaining terminals of the coil, which are below the secondary terminals, are joined to the battery, which is conventionalized for the sake of simplicity. In the system shown at Fig. 265, B, the terminals on the magneto and those on the coil are likewise numbered, and there should be no difficulty in tracing these and making the proper connections if this diagram is used as a guide.

The Remy transformer coil system is shown at Fig. 266, the appearance and dimensions of the dash coil and the method of installation are clearly shown at A. It will be observed that at one end of the coil there are two terminals, one marked "Bat.," the other "R.," which are wired to the dry cell battery, as shown. On the back of the coil is the secondary terminal, clearly outlined at B, which runs to the center of the distributor. The magneto shown is intended for six cylinder ignition and therefore has six distributing terminals, to be connected with an equivalent number of spark plugs. In order to simplify the wiring when the Remy system is employed, the primary wire group, which consists of three wires, has the insulation of each conductor a different color. One is yellow, one green, and the remaining one red. The red wire, which is attached to the grounding terminal on the magneto base, goes to the center terminal on the side of the coil that has the three primary terminals and which is shown at B. This would be the right side if viewed from the front, while the battery terminals are on the left side, if the coil is looked at from the switch end. The yellow wire is connected to the contact screw on the breaker box and goes to the terminal on the side of the coil nearest the dash. The green wire runs from the screw on the magneto base to the remaining terminal on the coil.

Dual Magneto Systems.—When the high tension magneto was first introduced it was looked upon in some quarters by conservative manufacturers and motorists with some degree of suspicion, as its reliability had not been thoroughly established. Sometimes difficulty was experienced in starting a large engine directly from the magneto because it could not be turned over fast enough with the hand crank to turn the magneto armature at sufficient speed to produce a strong spark. In order to provide an emergency sys-

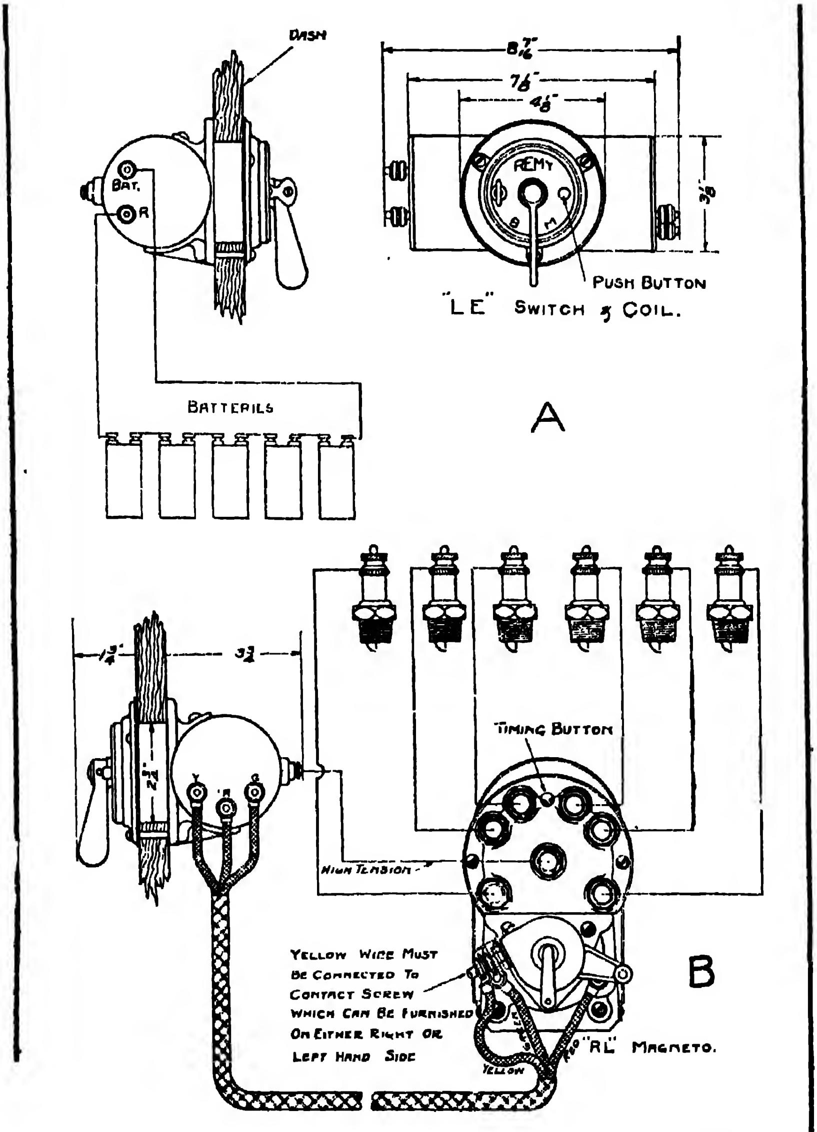


Fig. 266.—The Remy Ignition System.

tem of ignition and one that could be used for starting, the makers of high tension magnetos evolved what are termed "dual systems." The magneto utilized is practically the same as that used in the simple high tension systems, except that the contact breaker had a battery timer added which was used to interrupt a battery current. The reason for adding the battery timer and not using the magneto contact breaker was that a short contact was necessary to obtain satisfactory operation from batteries, which the regular magneto contact breaker did not furnish. As the writer has previously explained, the points of a magneto contact breaker are kept in contact until interrupted by the cam. If these were used on a battery the current would be flowing through them all the time they were in contact, which would produce current waste. With the battery timer incorporated on the contact breaker the circuit is established only at the instant the spark is needed in the cylinder. The systems shown at Fig. 267 are of Simms design, the only difference being in the number of terminals provided on the coil. In the system at A four terminals are used. In that at B, but three are employed. The only difference in the wiring is the connections of the battery terminals. On the four terminal coils two of these are joined to the battery. On the three-terminal coil the wire that runs to point 1 of the magneto, as shown at B, also is joined to the positive terminal of the storage battery.

The Bosch Dual system, which is shown at Fig. 268, has six terminals on the back end of the coil. The coil is attached to the dashboard, as indicated, in the upper right hand corner, and carries the switch and the starting button on its face. The coil is of the vibrator type. The terminals are all numbered and the wiring may be readily traced, as the points to which they connect on the magneto are numbered to correspond. In this system, instead of using the usual high tension pencil connecting the collector brush to the center of the distributor, the high tension brush terminal 3 is joined to a terminal on the spark coil, while terminal 4 of the spark coil is joined to the central distributing brush 4 of the magneto. Terminal 6 of the coil is grounded, terminal 5 of the coil runs to one of the battery terminals, the other one being grounded. This leaves terminals 1 and 2 on the coil, No. 1 being connected to

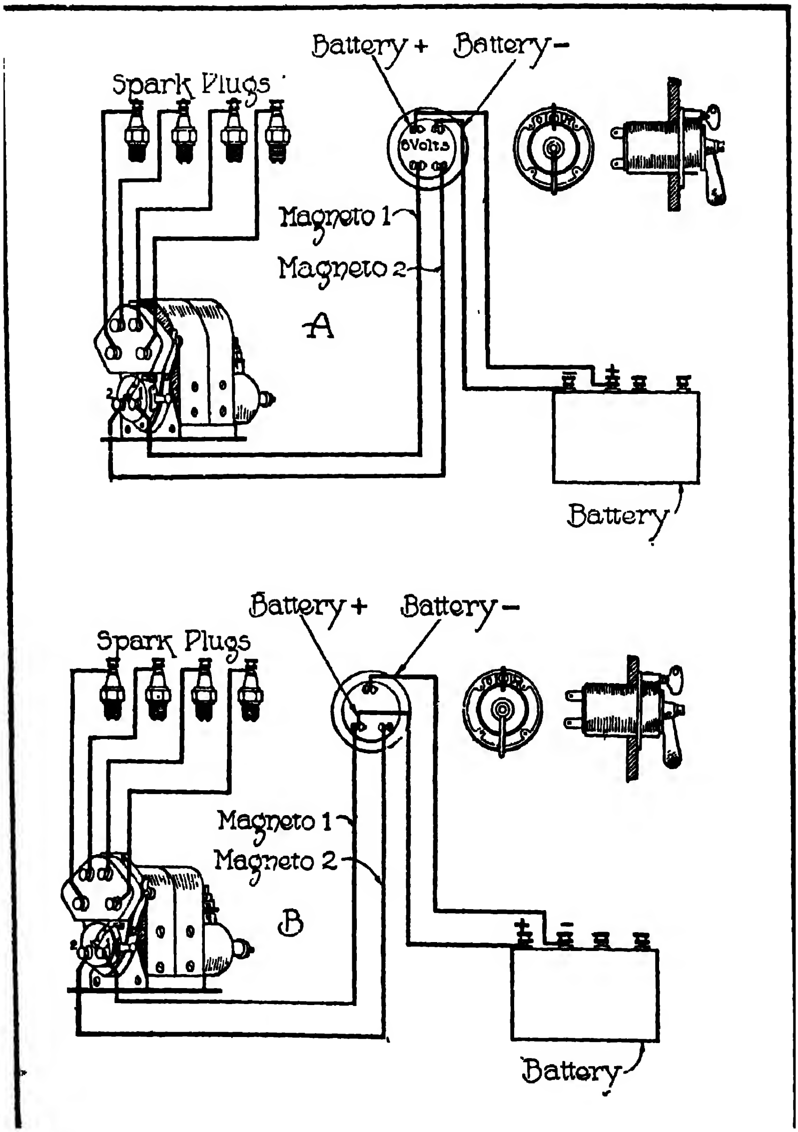


Fig. 267.—Wiring True High Tension Magneto to Obtain Dual Ignition System.

a terminal at the side of the battery contact breaker, while terminal No. 2 attaches to a terminal on the side of the magneto contact breaker. With a system of this kind or with either of those shown at Fig. 267, it is possible to short circuit the coil by pressing in on a starting button, which makes the vibrator buzz even if the primary contact breaker on the magneto is not making contact. This permits of starting the engine directly on the spark when

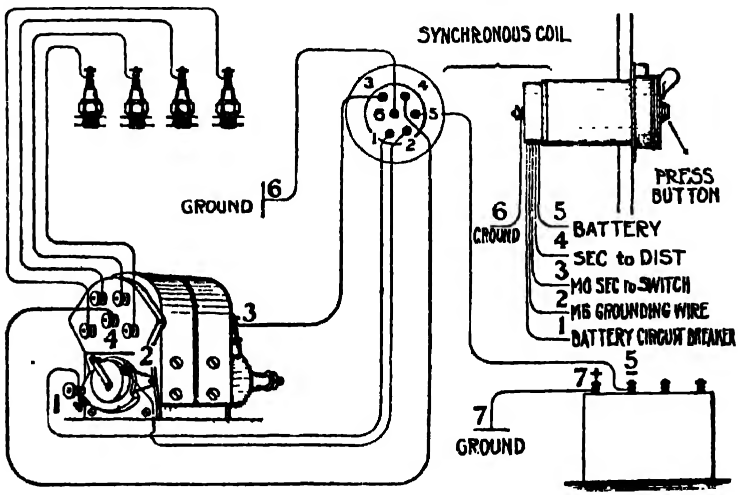


Fig. 268.—The Bosch Dual System.

they are of the four or six cylinder form, providing they have not been stopped long enough for the gas to leave the cylinders.

Master Vibrator Ignition Systems.—Practically the only car at the present time using the individual unit system of ignition is the Ford, the complete wiring diagram of which is clearly shown at Fig. 270, in the relation the parts actually occupy in the car. It will be observed that the induction coil has ten terminals, six of these being for the primary circuit and four for the secondary wires. The upper terminals of the coil are primary and run to the timer segments. The four secondary terminals are connected to the spark plugs as indicated, while the remaining two terminals,

which are at the bottom of the coil, are joined to the magneto terminal and to the battery respectively. In the system outlined each coil has a separate vibrator.

Many Ford cars have been supplied with what is known as a master vibrator, which is a magnetic circuit breaker intended to perform that function for all of the coils. It is claimed that a device of this character produces synchronism of the ignition spark,

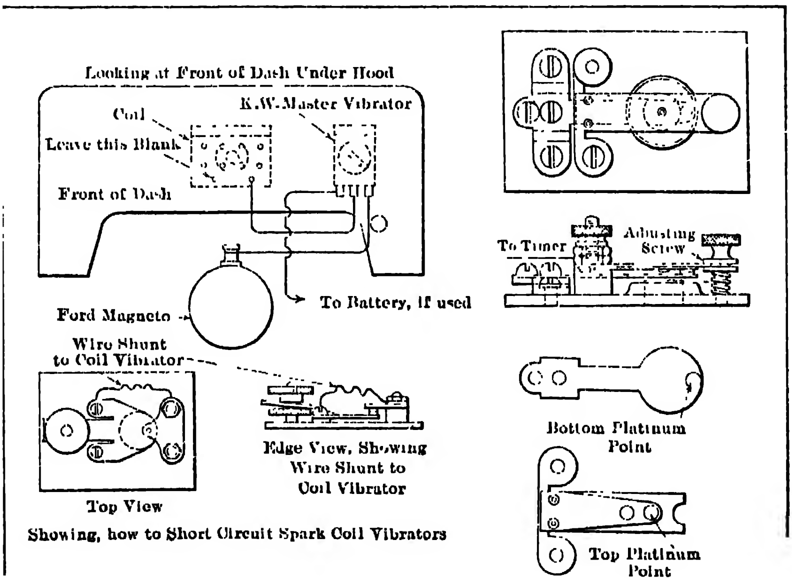


Fig. 269.—Method of Using Master Vibrator in Connection with Four Unit Coil.

which is not possible to obtain where four separate vibrators are used on account of some of these being tuned up faster than the others. It is contended that this makes a smoother-running engine and one delivering more power. A master vibrator unit that enjoys wide sale is of K-W manufacture and is designed especially for use with Ford cars. The method of wiring the vibrator is clearly outlined in the upper left hand corner at Fig. 269. As the vibrator unit carries a switch on its face, it has three terminals at the

bottom, the center one of which is connected to one of the regular terminals of the spark coil, leaving the other one blank. One of the outside terminals of the master vibrator is coupled to the magneto, the other to a battery. The switch of the main coil is used only on one contact button, and may be left on that button, as the battery or magneto may be thrown in circuit at will by the switch

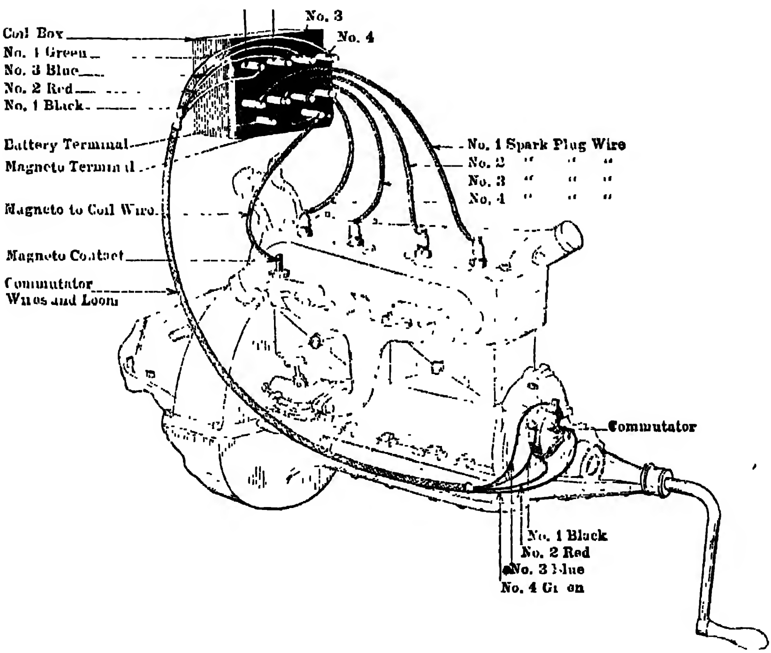


Fig. 270.—The Ford Ignition System.

on the master vibrator coil. It is necessary to short circuit the regular vibrators in order to put them out of commission. This is done by running a wire between the vibrator springs and the bridge carrying one of the contact points, as shown at the bottom of Fig. 269. Another method of short circuiting the vibrator is to keep the points in contact by wedging a piece of wood, rubber or

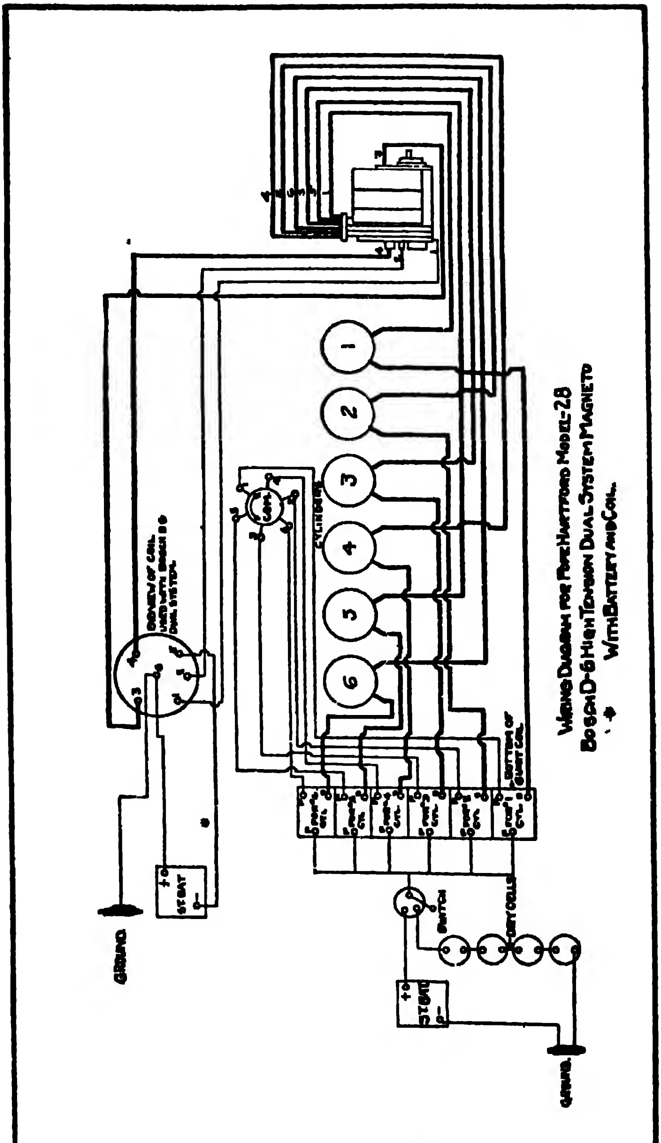


Fig. 271.—Wiring Diagram of Triple Ignition System Used on Six Cylinder Motor.

cardboard under the vibrator spring between the core of the coil and the vibrator. Keeping the points in contact in this manner is equivalent to short circuiting them by the wire shunt.

When but one vibrator is used the contact points must be made larger than those on the individual vibrators, because it does four times as much work. The construction of the K-W vibrator is clearly shown at Fig. 269, and in view of the instructions that have been previously given for the care and adjustment of these devices it is not necessary to describe its construction. The instructions given for adjusting the vibrator are very simple, it being merely necessary to observe if there is a space of $\frac{1}{64}$ inch between the platinum contact points when the vibrator spring is held down firmly on the iron core. A gauge made of $\frac{1}{64}$ inch thick steel may be placed between the contact points until the adjusting screw is screwed down to a point where the gauge can be pulled out without much trouble. This will give the proper distance for the armature or bottom spring to travel.

Double and Triple Ignition Methods.—There are many cars in operation to-day which utilize double and triple ignition systems. On some of these it is possible to have three practically independent means of supplying the ignition spark. As will be apparent, the wiring of a triple ignition system is apt to be much more complex than that of the simpler methods now in vogue. In the ignition system outlined at Fig. 271, which has been used on a six cylinder car, it will be evident that in addition to the usual Bosch D-6 dual magneto an entirely independent individual spark coil and battery timer system is included. Two sets of plugs are used, one serving both magneto distributor systems, while the other is connected to the individual coil units. The connections of the magneto system are no different than in the regular dual system previously described, while those of the battery and coil may be easily determined by a close study of the diagram. The primary timer has six contacts, one of which serves each ignition coil. As the firing order of this engine is 1-5-3-6-2-4, the wires from the timer must run to the individual unit coils in the same order so as to have the cylinders fire in proper sequence. For example, the wire from the contact No. 1 of the timer runs to coil No. 1,

next in order is contact No. 5, which is wired to coil unit No. 5. Following this comes timer contact No. 3, which supplies current to coil No. 3. While the individual spark coils are connected in order, i.e., coil No. 1 is joined to spark plug and cylinder No. 1, coil No. 2 to spark plug and cylinder No. 2, and so on the timer contact must be numbered according to the firing order. It will be apparent that two sources of ignition current are provided for the battery and coil systems, one being a storage battery, the other a set of dry cells.

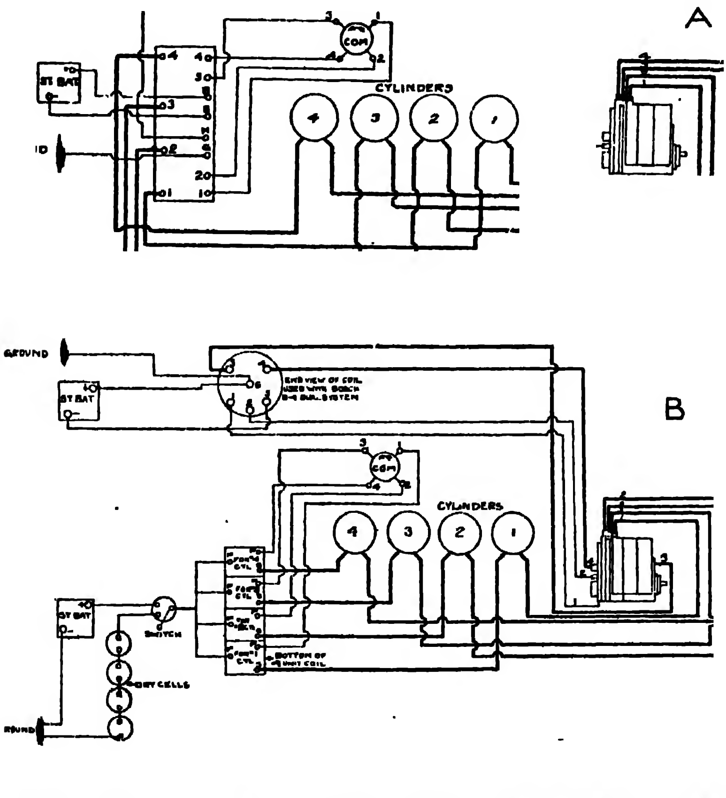


Fig. 272.—Wiring Diagram of Double Ignition System at A; of Triple Ignition System at B, both for Four Cylinder Engines.

A double ignition system in which a true high tension magneto is used and a four unit vibrator coil and four point timer is shown at A, Fig. 272. This ignition system is for a four-cylinder motor having a firing order of 1—3—4—2. At B, Fig. 272, a triple ignition system for a four-cylinder engine is shown, this being practically the same as that outlined at Fig. 271, except that the wiring diagram is somewhat simpler owing to the lesser number of cylinders. The advantage of a double ignition system is that one can determine if irregular engine operation is due to the ignition system or not very easily by running the engine first on one system, then on the other. If the engine runs as it should on the battery system after it has been misfiring on the magneto it is reasonable to assume that some portion of the magneto system is not functioning properly. If the engine runs well on the magneto, but not on the battery, the trouble may be ascribed to failure in the chemical current producer or its auxiliary devices. On the other hand, if the engine does not run well on either ignition systems, it is fair to assume that the trouble is not due to faulty ignition.

Two Spark Ignition.—Most racing and a few pleasure cars have been equipped with two spark magneto ignition systems, the idea being to secure greater power and speed due to the use of two spark plugs in the cylinder. While systems of this kind are rare, it may be well for the repairman to become familiar with the principles involved in case he should ever be called upon to install a two spark magneto or to make repairs on some speedster model so equipped. When a magneto is employed in connection with two spark ignition it is common practice to provide two separate distributors and in some cases a double wound armature having two sets of windings served by a common contact breaker. In the system shown at A. Fig. 273, a two spark magneto is employed in connection with the simple dash switch wired as indicated, by which one may obtain the use of but one spark with the switch lever in the position shown and the double spark if the switch lever is rocked to the other extreme, or on the line marked "2." If the lever is swung to the left or on a line with that indicated "O," no spark will pass through the engine, as the magneto will

be grounded. The system outlined at B is that of a two spark magneto that can be used in connection with a vibrator coil and battery, as in the dual system previously described. In addition to the switch on the coil, a two point switch is placed on the dash in order to obtain single or double spark ignition as desired.

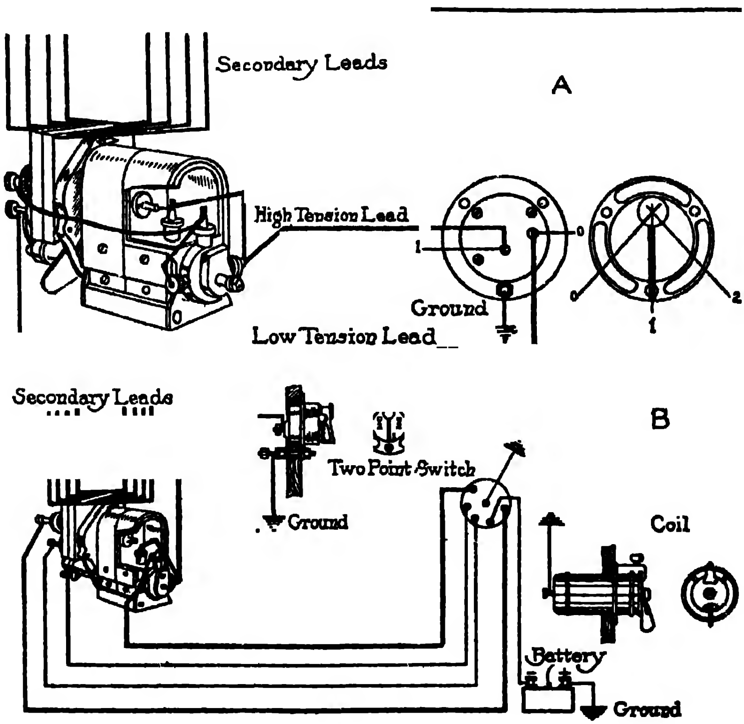


Fig. 273.—Outlining Use of Two Spark High Tension Magneto.

Timing Battery Ignition Systems.—In timing a motor using a battery ignition system with individual vibrator coils to supply the current to respective cylinders, the first thing to ascertain is the firing order of the engine to be timed. The diagram, Fig. 274, shows all components of a battery ignition system, also a sectional view of one of the cylinders of the engine, showing the position

of the piston when the spark should occur in the cylinder with the primary timer fully advanced. When the primary timer is fully retarded the spark will take place after the piston has reached the top of its stroke and has started to go down on the explosion stroke. The four unit spark coil has a two point switch on its face and has ten terminals. Four of these which are protected by heavy insulators or bushings of hard rubber run to the spark plugs as indicated. These are the secondary terminals. The two primary terminals under the switch are connected to the positive poles of the dry cell and storage batteries respectively, the negative terminals of the two batteries being joined together by a common wire and grounded. This leaves four primary leads which go to insulated terminals connecting with the segments of the timer.

The method of timing an engine is very simple. The spark advance lever on the steering wheel is advanced fully. The inlet valve of cylinder No. 1 is watched as the engine is turned by the hand crank. Just after the inlet valve closes which indicates that the piston has started to go up on its compression stroke the piston travel may be gauged accurately as it moves up by the timing rod inserted through a petcock in the top of the cylinder or through a valve cap opening. If the engine is not provided with a relief cock or spark plug that will permit the use of the gauge rod, the flywheel markings may be utilized to determine the center corresponding to the end of the piston upward movement. The vibrator of coil connected to cylinder No. 1 should begin to buzz with the timer casing in full advanced position before the piston reaches the end of its upward stroke. The amount of crankshaft travel is about 30 degrees from the point where the spark takes place to that where the piston reaches the top of its stroke. If the timer casing is set in full retard position the spark should take place 30 degrees of the crankshaft travel after the piston has left the end of its compression stroke. Some engines have the spark set 45 degrees advance. With the spark advance lever set about half way of its travel the spark may be made to occur just when the piston reaches the end of its compression stroke, or on top center. It is necessary to provide a wider range of spark advance on a

battery and coil ignition system than when a magneto is used, as it is said that a range of advance of 60 degrees is sufficient for four-cylinder motors and 27 degrees for six-cylinder motors with magneto ignition.

In timing a strange car it is easy to tell whether the movement of the spark lever advances or retards the timer case by noting

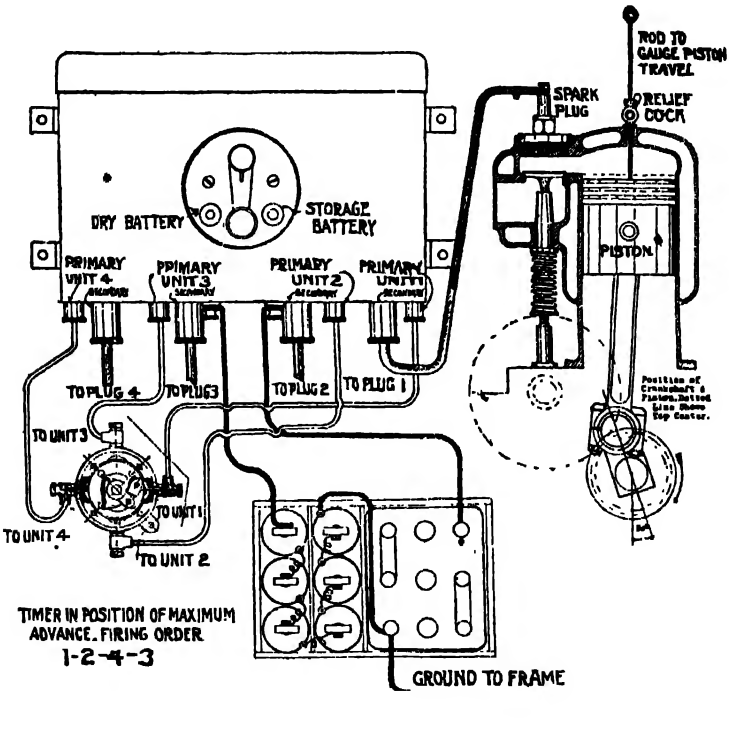


Fig. 274.—Diagram Showing Method of Timing Four Cylinder Battery Ignition System.

the direction of movement of that member. If the spark advance lever is pushed in a certain direction, say from the point on the sector nearest the driver to the other extreme, and the segments on the timer move to meet the advancing contact roller, it is evi-

dent that a movement of the spark advance lever from front to rear advances the ignition. If the timer case oscillates so the segment moves away from the advancing contact roller, that movement of the spark lever retards the ignition. In most timers the rotating contact member is fastened to the shaft in such a way that it may be moved independent of engine rotation, if desired, by releasing the fastening. Sometimes it is held on a tapered shaft by a clamping nut, in other constructions it is driven by a hollow shaft which is set screwed to the timer driving shaft the position of which can be changed as desired. In every case the roller should be set in contact with the segments joined to coil unit No. 1, the remaining terminals being wired according to the firing order and the direction of rotation of the timer brush. In the diagram now under discussion after the roller leaves unit No. 1 segment it will go to that in connection with unit No. 2, then to the one joined to unit No. 4, and finally to the terminal conveying the electrical current to unit No. 3. This means that the plug in cylinder No. 1 fires first, followed by those in cylinders 2, 4, 3, in the order named. With the switch lever in the position shown or between the two contact buttons, the ignition is interrupted and battery current cannot flow to the coil unit. If the switch lever is moved to the button on the right marked "storage battery," the secondary current producer will furnish ignition. If moved to the button on the left, the dry cells will be brought into action. The same method is employed in timing a two, three or six-cylinder motor, the only precaution to be observed being to run the wires from the timer to the coils so the cylinders will fire in proper order.

At one time secondary distributor systems using a single unit vibrator coil for firing a multiple cylinder engine were very popular, but at the present time few cars use the long contact timer and distributor combination. The modern cars that employ battery ignition use a short contact timer and a non-vibrator coil unit. Popular systems of this nature are the Atwater-Kent and the Delco, both of which have been previously described. Practically the same method of timing is employed with these systems except that there is but one primary terminal on the contact breaker por-

tion of the distributor which is joined to the corresponding terminal of the spark coil. A proper distribution of current to the cylinders is made by connecting the distributing terminals to the plugs in proper firing order, same as advised with a magneto.

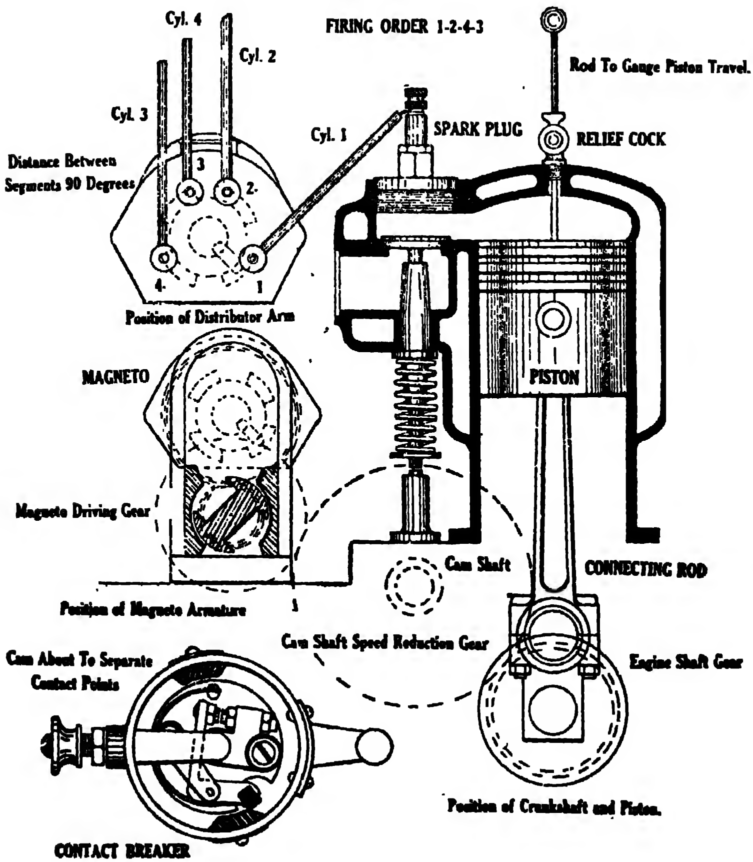


Fig. 275.—Diagram Showing Method of Timing Four Cylinder High Tension Magneto Ignition System.

Timing Magneto Ignition Systems.—An ideal method of magneto placing and one followed by a large number of manufacturers

is shown at Fig. 275. In this the device is fitted to a four-cylinder engine, and as the armature must be driven at the same speed as the crankshaft, it is necessary to use but one extra gear, that being the same size as the engine shaft pinion and driven by the camshaft speed reduction gear. Incidentally, the sketch illustrates the best method of timing the magneto, which is one of the direct high-tension type. The position of the various parts is clearly shown. Having fixed the magneto to the engine crankcase, the driving pinion, or one of the members of a flange or Oldham coupling, is put loosely on the tapered end of the armature shaft, and the cover to the distributor and the dust cover of the contact breaker are removed to allow one to control the position of the armature. The motor is now turned over by hand so the piston in the first cylinder is at top center, which can be determined either by watching the crankshaft through a suitable opening in the engine base, by reading the marks on the flywheel rim, or by inserting a wire through a compression relief petcock or spark plug hole, if either of these is at the top of the cylinder.

The armature of the magneto is then brought to the position indicated in sketch, which represents the fitting of a magneto that is turning clockwise when viewed from the driving end. The distance between the end of the armature and the pole piece should be between 14 and 17 mm or between .5511 inch and .6692 inch. This represents an advance of about .5 inch on a motor with a five-inch stroke. A graphic chart, prepared by the Bosch Company and reproduced at Fig. 243, shows the relation between piston travel and crankshaft movement for engines of different strokes very clearly. The armature is uncovered by removing the flat casing cover lying between the horseshoe magnets, this often carrying the safety spark gap (as shown at Figs. 256 and 258), and normally serving as a lid. If earlier timing be desired for any special purpose the gap may be widened a trifle, if it be thought the timing is too far advanced, the gap may be lessened. The contact breaker is fully advanced at this time and the contact points are just about to separate. Having placed everything in position as described, tighten the coupling on the taper shaft and ream out for a small taper pin.

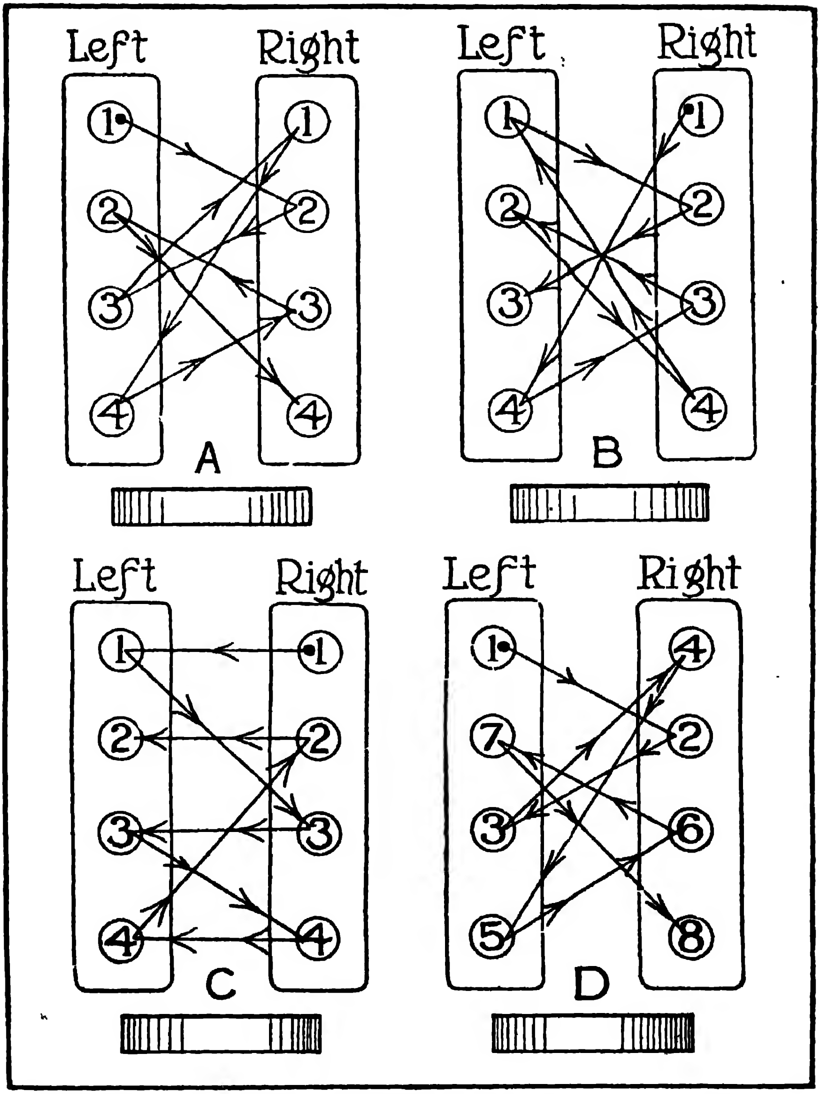


Fig. 276.—Firing Orders of Typical Eight Cylinder V Engines.

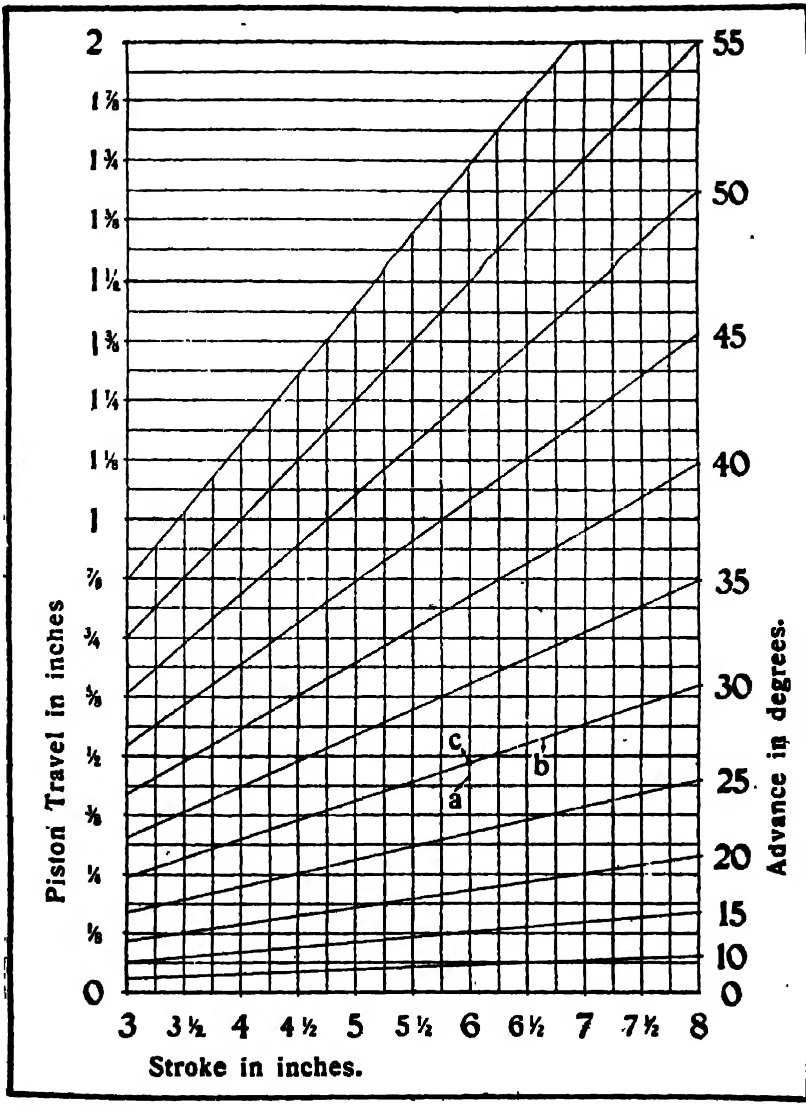


Fig. 277.—Chart Showing Piston Travel to Correspond to Different Degrees of Spark Advance for Motors of Various Strokes.

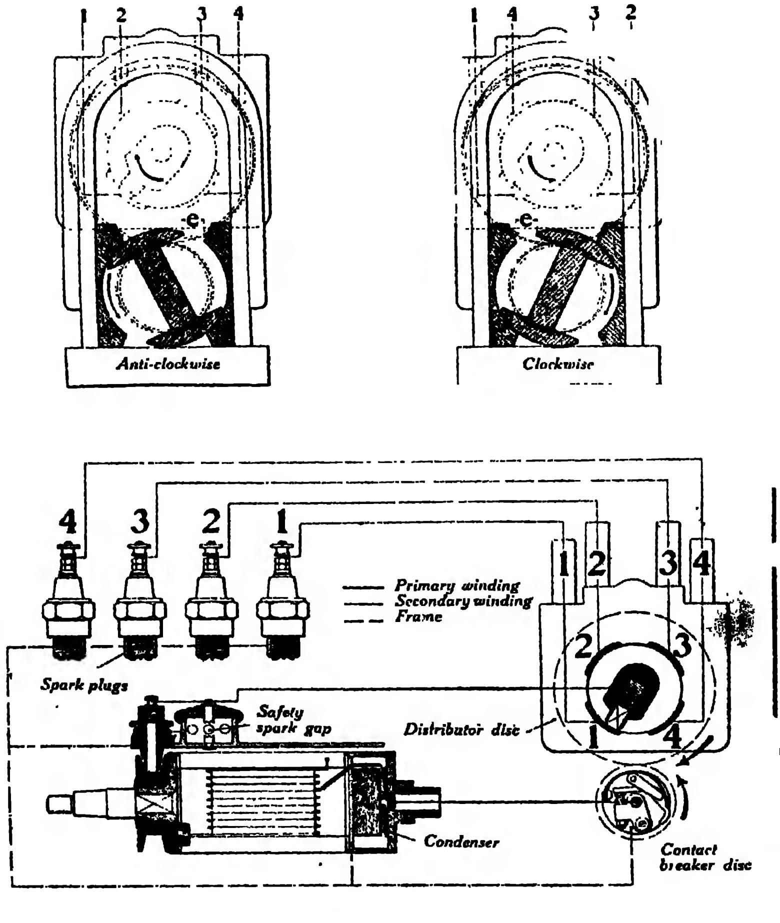
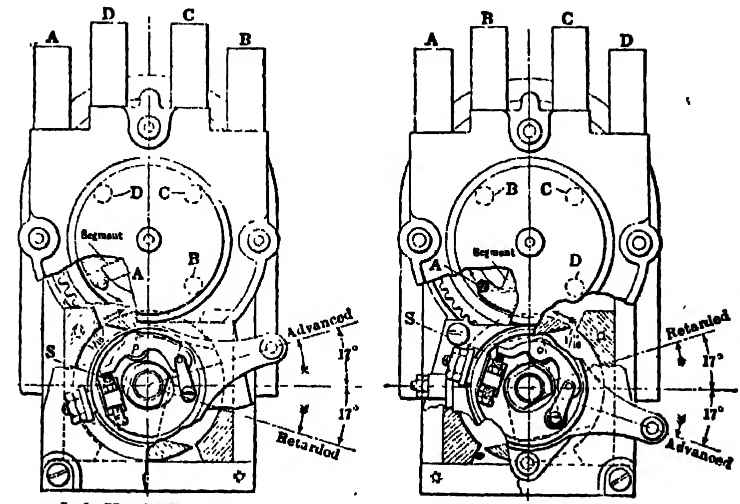


Fig. 278.—At Top, Showing Methods of Timing Bosch High Tension Magneto when Rotated in Either Direction. At Bottom, Simplified Wiring Diagram of Bosch High Tension Ignition System.

The connections to the various cylinders must be made in the order they fire (see following tabulation). When the cover to the distributor is off, see at which segment the brush is contacting. The wire to the spark plug in the first cylinder is then led to the terminal corresponding to this segment. Then the plug in the cylinder that is next to fire is coupled to the next segment, and so on. The numbers on the distributor show the order in which



Left Hand Magneto.
Looking at Machine from Driving End. Points (S) about to Open as Armature Core leaves Pole Piece about 1/16", Segment just under Brush.

Right Hand Magneto.
Looking at Machine from Driving End. Points (S) about to Open as Armature Core leaves Pole Piece about 1/16", Segment just under Brush.

Fig. 279.—Showing Methods of Timing Splitdorf Magneto.

the various contacts are brought in contact with the rotating distributing brush, and not that in which the cylinders fire. In the sketch the cylinders fire 1—2—4—3. Therefore, the segment number 3 is coupled to the plug in cylinder 4, and the segment 4 is connected to the plug in cylinder 3, which is thus the last to fire if the explosion takes place first in cylinder 1. The direction of the distributor brush rotation, if driven by the usual form of gear-

ing, is opposite to that of the magneto armature. Obviously, if one cylinder is timed correctly, the remaining members will also fire at the proper time in the cycle of operations. The positions of the armature, distributing brush, contact breaker cam and piston are easily ascertained by inspection of drawing.

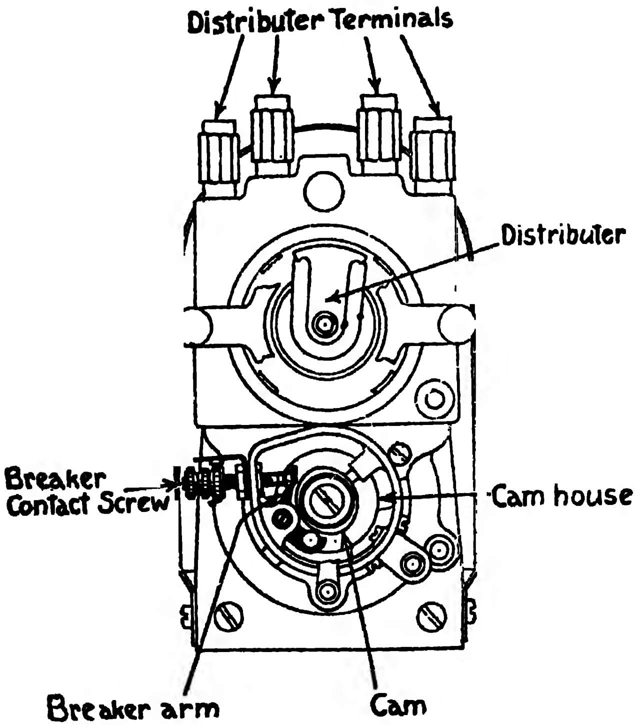


Fig. 280.—Front View of Remy Magneto, Showing Construction of Distributor and Contact Breaker.

Firing Order of Typical Engines.—The following information relative to timing of leading 1914 and 1915 models of American manufacture will prove of great value to the repairman called upon to repair many different makes of cars. It is well to remem-

ber, if the firing order is not known, that it can be easily determined by following the inlet valve movements in the cylinders and noting the order of opening of these members.

ABBOTT-DETROIT.

34–40 AND 44–50—FIRING ORDER 1–3–4–2.

BELLE ISLE—FIRING ORDER 1–5–3–6–2–4.

Magneto Setting—Piston dead centre, lever fully retarded. Full advance, spark occurs with crankshaft 13 degrees ahead of dead centre. Contact point gap .018 inch.

ALLEN.

40—FIRING ORDER 1–2–4–3.

Magneto Setting—Piston top dead centre, lever fully retarded.

AMERICAN.

SCOUT—FIRING ORDER 1–3–4–2.

644, 646 AND 666—FIRING ORDER 1–5–3–6–2–4.

Magneto Setting—Three-quarter inch after dead centre on flywheel.

ARBENZ.

FIRING ORDER 1–3–4–2.

Magneto Setting—Piston .03125 inch late, lever fully retarded.

AUBURN.

4–40 AND 4–41—FIRING ORDER 1–3–4–2.

Magneto Setting—Piston .03125 inch late, lever fully retarded.

6–46 AND 6–45—FIRING ORDER 1–4–2–6–3–5.

Magneto Setting—Piston top dead centre, lever fully retarded.

BUICK.

B 24, 25, 36, 37 AND 38—FIRING ORDER 1–3–4–2.

Delco—With timer cam fully retarded, spark occurs 40 degrees past upper dead centre on firing stroke. With hand spark lever half-way advanced, spark occurs at approximately top dead centre.

B 55—FIRING ORDER 1–4–2–6–3–5.

Delco—Piston dead centre with timer fully retarded.

CASE.

25 R and 35 S—Firing Order 1–3–4–2.

Magneto Setting—One thirty-second inch before top dead centre.

40 O—Firing Order 1–3–4–2.

Magneto Setting—One-sixteenth inch after top dead centre.

CHALMERS.

24—Firing Order 1–4–2–6–3–5.

Magneto Setting—One and one-half inches past centre, lever fully retarded.

CHANDLER.

Six—Firing Order 1–5–3–6–2–4.

Magneto Setting—Piston dead centre, lever fully retarded.

COLE.

Four—Firing Order 1–3–4–2.
Six—Firing Order 1–5–3–6–2–4.

Delco—Piston dead centre, distributor fully retarded.

CONTINENTAL.

27—Firing Order 1–3–4–2.

Magneto Setting—Three-quarter inch after dead centre on flywheel.

GLIDE.

36 and 30—Firing Order 1–3–4–2.

Westinghouse—Piston top dead centre.

GRANT.

M—Firing Order 1–3–4–2.

Magneto Setting—Lever fully advanced, piston .3125 inch before top dead centre.

HAYNES.

28—Firing Order 1–3–4–2.

Magneto Setting—One sixty-fourth inch advanced on down stroke.

26 and 27—Firing Order 1–4–2–6–3–5.

Magneto Setting—One sixty-fourth inch advanced on down stroke.

HUDSON.

6–40 AND 6–54—FIRING ORDER 1–5–3–6–2–4.

HUPMOBILE.

32—FIRING ORDER 1–2–4–3.

Magneto Setting—Piston dead centre, lever fully retarded.

IMPERIAL.

34 F B, 32 AND 34 4 M—FIRING ORDER 1–2–4–3.
54 AND 44–6—FIRING ORDER 1–5–3–6–2–4.

Magneto Setting—Points break with piston on dead centre.

INTER-STATE.

45—FIRING ORDER 1–5–3–6–2–4.

JACKSON.

MAJESTIC AND OLYMPIC—FIRING ORDER 1–3–4–2.

Magneto Setting—Piston .125 inch before top centre.

SULTANIC—FIRING ORDER 1–5–3–6–2–4.

Magneto Setting—Piston .125 inch before top centre.

JEFFERY.

93—FIRING ORDER 1–3–4–2.
96—FIRING ORDER 1–4–2–6–3–5.

Magneto Setting—Piston dead centre, lever fully retarded.

KEETON.

F—FIRING ORDER 1–5–3–6–2–4.

Magneto Setting—Points break 6.5 degrees before centre.

KING.

B—FIRING ORDER 1–3–4–2.

Magneto Setting—Points break with lever fully retarded from centre o .5 inch past on flywheel.

KNOX.

44 AND 45—FIRING ORDER 1–3–4–2.

Magneto Setting—Piston .75 inch before top centre, lever fully re-arded. Battery, piston .375 inch before top centre.

KRIT.

L—FIRING ORDER 1-3-4-2.

Magneto Setting—Piston .125 inch before top dead centre, lever fully retarded.

LEWIS.

SIX—FIRING ORDER 1-5-3-6-2-4.

Magneto Setting—Piston top dead centre, lever fully retarded. Full advance equals .234375 inch of piston stroke.

LOCOMOBILE.

48 LD AND RD, 38 RD AND LD—FIRING ORDER 1-5-3-6-2-4.

Magneto Setting—Three-eighths to .4375 inch before top dead centre, lever fully advanced.

LOZIER.

FOUR—FIRING ORDER 1-3-4-2.

77—FIRING ORDER 1-4-2-6-3-5.

Magneto Setting—Piston dead centre, lever fully retarded.

LYONS-KNIGHT.

K4—FIRING ORDER 1-3-4-2.

Magneto has six-inch range on 20-inch flywheel from one inch past centre to five inches before.

MAXWELL.

25-4 AND 35-4—FIRING ORDER 1-3-4-2.

50-6—FIRING ORDER 1-4-2-6-3-5.

Magneto Setting—Points break with piston on dead centre, lever fully retarded.

MOLINE-KNIGHT.

26-50—FIRING ORDER 1-3-4-2.

Magneto Setting—Piston top dead centre.

MOON.

42—FIRING ORDER—1-3-4-2.

6-50—FIRING ORDER 1-5-3-6-2-4.

Delco—Spark breaks on centre in retarded position.

NATIONAL.

40—FIRING ORDER 1–3–4–2.

Magneto Setting—Piston .0625 inch past top dead centre, lever fully retarded.

SIX—FIRING ORDER 1–5–3–6–2–4.

Magneto Setting—Piston .125 inch before top dead centre, lever fully retarded.

NORWALK.

C AND D—FIRING ORDER 1–4–2–6–3–5.

Atwater Kent—Piston is .093 inch past centre with distributor set at retard.

OLDSMOBILE.

54—FIRING ORDER 1–5–3–6–2–4.

Delco—Spark occurs at piston dead centre with hand spark lever fully retarded or .390625 before dead centre with lever fully advanced.

OVERLAND.

79—FIRING ORDER 1–3–4–2.

Magneto Setting—One and one-quarter inches after dead centre (flywheel), lever fully retarded.

PACKARD.

2–38—FIRING ORDER 1–4–2–6–3–5.

Magneto Setting—Piston .5 inch before top centre, lever fully advanced.

PAIGE.

25 AND 36—FIRING ORDER 1–3–4–2.

Magneto Setting—Place No. 4 piston on top dead centre (Compression stroke). Points should just begin to break.

PIERCE-ARROW.

SIXES—FIRING ORDER 1–5–3–6–2–4.

Magneto Setting—Magneto mark on flywheel should be 4.8125 inches ahead of 1 and 6 top centre and 1 showing in timing window. Piston is .5 inch before top dead centre of 33 degrees of crank circle. Battery spark occurs with piston 2.125 inches before top dead centre or 75 degrees of crank circle with spark lever fully advanced.

PILOT.

50—Firing Order 1–3–4–2.
60—Firing Order 1–5–3–6–2–4.

Magneto Setting—Points break with lever fully retarded and piston on dead centre.

POPE-HARTFORD.

35—Firing Order 1–2–4–3.

Magneto Setting—Piston top dead centre. Maximum advance of magneto .5 inch on piston travel.

PREMIER.

6–48 and Weidely—Firing Order 1–4–2–6–3–5.

Magneto Setting—Piston dead centre, lever fully retarded.

REGAL.

C, T, N and NC—Firing Order 1–2–4–3.

Magneto Setting—Piston top dead centre, lever fully retarded.

REO.

Fifth—Firing Order 1–3–4–2.

Remy System—Piston top dead centre when indexing button on distributor engages.

SAXON.

A—Firing Order 1–3–4–2.

Atwater Kent—Piston dead centre, distributor fully retarded.

SIMPLEX.

38 and 50—Firing Order 1–3–4–2.

Magneto Setting—Piston .015625 inch before top dead centre.

75—Firing Order 1–3–4–2.

Magneto Setting—Piston dead centre or slightly after.

SPEEDWELL.

H—Firing Order 1–5–3–6–2–4.

Magneto Setting—Points break with piston at top dead centre.

Rotary—Firing Order 1–5–3–6–2–4.

Magneto Setting—One-sixteenth inch after top dead centre, lever fully retarded.

STEARNS-KNIGHT.

Four—Firing Order 1–2–4–3.
Six—Firing Order 1–5–3–6–2–4.

Magneto Setting—Piston top dead centre, points breaking.

STEVENS-DURYEA.

C 6—Firing Order 1–4–2–6–3–5.

Magneto Setting—Figure 1 showing in timing window, 25 degrees before top dead centre (flywheel).

STUDEBAKER.

Four—Firing Order 1–3–4–2.
Six—Firing Order 1–5–3–6–2–4.

Remy System—Spark occurs .75 inch after top dead centre.

VELIE.

5 and 9—Firing Order 1–3–4–2.
10—Firing Order 1–5–3–6–2–4.

Magneto Setting—Piston top dead centre.

WINTON.

Six—Firing Order 1–5–3–6–2–4.

Magneto Setting—Piston .125 inch after top dead centre, lever fully retarded and points breaking.

Battery System Hints.—See that the wires are heavy enough to carry the current and that all the connections are kept clean and bright as every corroded joint causes needless resistance.

Inspect battery connections, etc., occasionally, as they have a habit of working loose.

Look well to the ground connection, which should be very securely made and placed where it will not corrode.

Be sure the battery, especially if dry cells are used, is where it cannot get wet, as the paste-board may absorb sufficient moisture to short circuit the cells.

See that all wires are securely fastened so that they cannot by any means rub or chafe against either wood or metal parts; especially the secondary wires.

Frequently examine the condition of the plugs, as plug trouble is often looked for elsewhere.

Don't allow the wires to become water- or oil-soaked, as short circuiting will probably result.

Don't screw down electrical connections with the fingers, as a tight joint cannot be made. Use pliers.

Don't allow the storage battery to get so far discharged that it will not operate the coil. See that the vibrators are set as lightly as possible to run the engine without skipping, otherwise they will waste current.

Don't take it for granted you have ignition trouble every time the engine stops.

Don't start out knowing the battery to be nearly exhausted, as it may run all right to start with, but will probably go out of business at a most inopportune time and place.

Don't adjust the coil vibrator for the biggest possible spark, as it wastes current.

Don't think the coil is no good if the vibrators do not buzz exactly alike.

Don't test storage batteries with an ammeter unless they are charging or discharging.

Don't strain the coil by disconnecting the secondary wires completely so that no spark can jump, or by testing how far it will jump.

Don't screw or nail anything on to the coil box, as you may injure it.

Don't tolerate any loose wires or poorly made connections. Fix them at once.

CHAPTER VI

MOTOR STARTING AND LIGHTING SYSTEMS

Leading Methods Outlined—Mechanical Starters—Pneumatic Starters—Presto-lite Primer—Electric Starter Forms—Generator and Starting Motors—Generator Driving Means—Starting Clutches and Gearing—Switches and Current Controlling Devices—Typical Wiring Diagrams—Delco System—Bijur—Hartford, Auto-Lite—Gray & Davis—Chalmers—Entz—Remy—Faults in Motors and Generators—Faults in Wiring—Typical Lighting Systems.

One of the pronounced developments of the last two or three years has been the general adoption of various starting means for setting the engine in motion without recourse to the usual form of hand crank. Some of these motor starting systems merely replace the usual hand crank with some means of turning the motor over without leaving the seat by purely mechanical connections. Others, on 1912 and 1913 models of a few cars, depend on air pressure, while the most popular and generally applied forms to 1916 model cars depend on electricity as a source of power for a small electric starting motor. Electric starting and lighting systems have been made in many forms, though the basic principles of operation are practically the same in all systems that can be grouped in several main classifications. It will not be possible to describe all in a general treatise of this nature, but if the features of the leading systems are outlined it will not be difficult for the repairman to became familiar with the principle of other systems which may be slightly different only in points of minor detail. Before discussing the electrical starting means, it will be necessary to give brief consideration to the mechanical and pneumatic starting systems which have received some degree of practical application and which are still advertised in trade prints.

Mechanical Starters.—While different makes of cars have been marketed using air starting systems, there has been no car offered with a mechanical starter. so wherever these are used they have

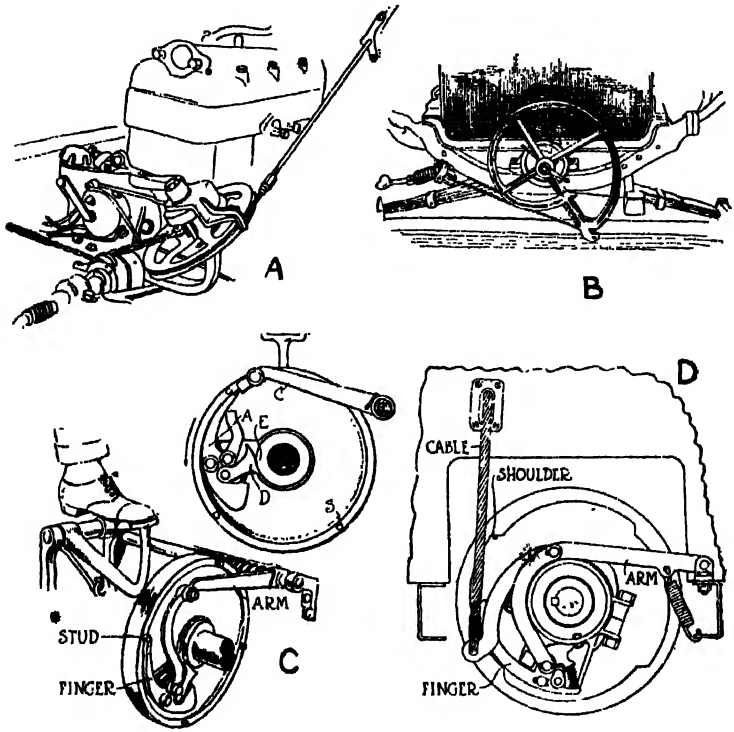


Fig. 281.—Showing Construction of Mechanical Devices for Starting Gasoline Engine from the Operator's Seat.

been applied by the owner of the vehicle and not the manufacturer. Owing to the wide distribution of the Ford automobile, and the fact that the makers make no provision for a self-starting motor, various forms of simple starters by which the motor may be cranked from the seat have been offered. Two of these are shown at the top of Fig. 281. That at A consists of a ratchet clutch

which is attached to the starting end of the crankshaft and which is operated by means of chain connection with the smaller pulley of a two diameter pulley wheel. The larger wheel carries a wire cable which is attached to a straight rod running through the dashboard and terminating in a handle convenient to the drivers hand. A pull on the spade type handle provided at the end of the rod will move the pulley wheel and produce a corresponding movement of the starting ratchet which turns the engine crankshaft over in the same way as the hand crank does. A modification of the device shown at A is outlined at B. This works on the same principle, except that an odd-shaped member is used to turn over the engine crankshaft. These devices are in no sense of the word "self-starters," but on light motor cars they provide an effective substitute in that the engine may be turned over without undue exertion and without leaving the seat. This is an advantage of some moment when the engine stalls in traffic, or under conditions where it would be inconvenient to get out of the car.

Two types of mechanical starters known as the Wilkinson are shown at the bottom of the illustration, Fig. 281. The one at D is operated by pulling a handle on the dash, the one at C by a pedal designed for foot actuation. The mechanism is such that the flywheel is pushed around by a lever which will engage with either a stud or a shoulder on the flywheel. The type at the left uses the studded flywheel, there being four of these marked "S." When the arm C is moved by depressing a pedal, the finger A contacts with one of the studs and turns the flywheel. Return engagement is produced by the large spring shown. In order to minimize liability of injury from backfire, the Wilkinson device is constructed so that the pawl D rises on the cam which bears against the collar E, and thus throws the finger out of engagement with the stud. One thrust of the pedal will turn the flywheel of a four-cylinder engine sufficiently to cause one cylinder to fire should ignition and carburetion and carburetion systems be functioning properly. The type at D is just as simple, but is modified somewhat in its construction. In this a hand lever is used to rotate the flywheel, and instead of using studs on the flywheel rim, four shoulders in the interior periphery do the work.

These shoulders may be cast with the wheel, or in some cars it is possible to have them cut in the flywheel. The operation is the same as that of the type previously described as the movement of the cable causes the finger to engage with one of the shoulders, and thus turn the flywheel.

The results obtained with any of these mechanical starters are not to be compared with that obtained from an electrical device which spins the motor much faster than normal hand-cranking speed, whereas the mechanical starter produces a movement of not more than half a revolution of the flywheel. Various forms of spring-operated starters have been devised and placed on the market, but these have not been very popular on account of their bulk and lack of reliability. The amount of power that can be stored in a spring is not great, and at the most the motor could only be turned over three or four revolutions. If the ignition or carburetion systems were not functioning just as they should be, it will be apparent that the spring would be unwound and incapable of starting the motor. In order to turn the motor over it is necessary with most of these starters to rewind the spring with a hand crank provided for the purpose. If the engine starts promptly the spring is rewound automatically by the engine, and as long as the engine starts without delay the starter is available for use. Practically all of these devices require special fittings, with the exception of those described for the Ford car, and as full instructions are furnished by their makers for application the repairman who is called upon to fit a mechanical starter may do so without trouble by following the instructions provided.

Pneumatic Starters.—Three prominent makes of automobiles which have been marketed in fairly large numbers, namely the Winton, Pierce-Arrow and Chalmers, have used pneumatic or air starters all of which have operated on exactly the same system. At the present time these cars are furnished with electrical starters of the conventional pattern. In case the repairman is called upon to repair one of the models equipped with an air starter, the writer believes it necessary to consider the arrangement of the parts and the method of operation briefly before considering the subject of electrical starters. All the components of typical sys-

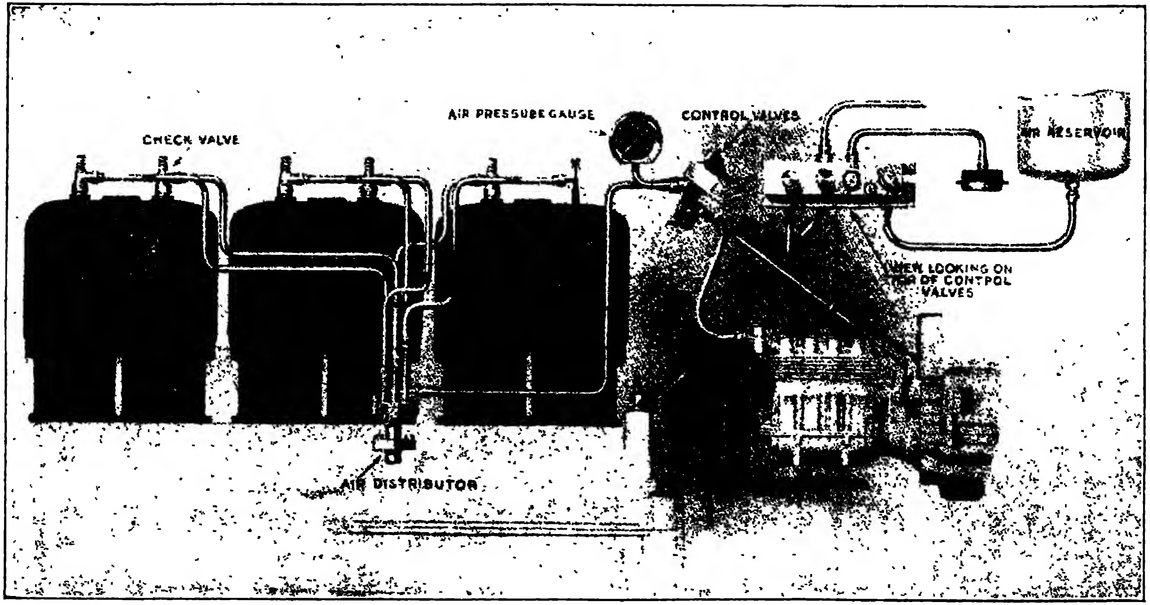


Fig. 282.—Diagram Showing Parts of Air Starting Systems Used on Some Early Models of Pierce-Arrow Automobiles.

tems, one of which was used on Pierce-Arrow cars, is shown at Fig. 282. It will be observed that an air pump of the four-cylinder type was attached to the gear box and driven from the counter shaft of that member. This supplied air to an air reservoir or container attached to the chassis. This container communicated with the top of an air distributor when a suitable control valve was open. An air pressure gauge is provided to enable one to ascertain the air pressure available. The top of each cylinder is provided with a check valve, through which air can flow only in one direction, i.e., from the tank to the interior of the cylinder. Under explosive pressure these check valves close. The function of

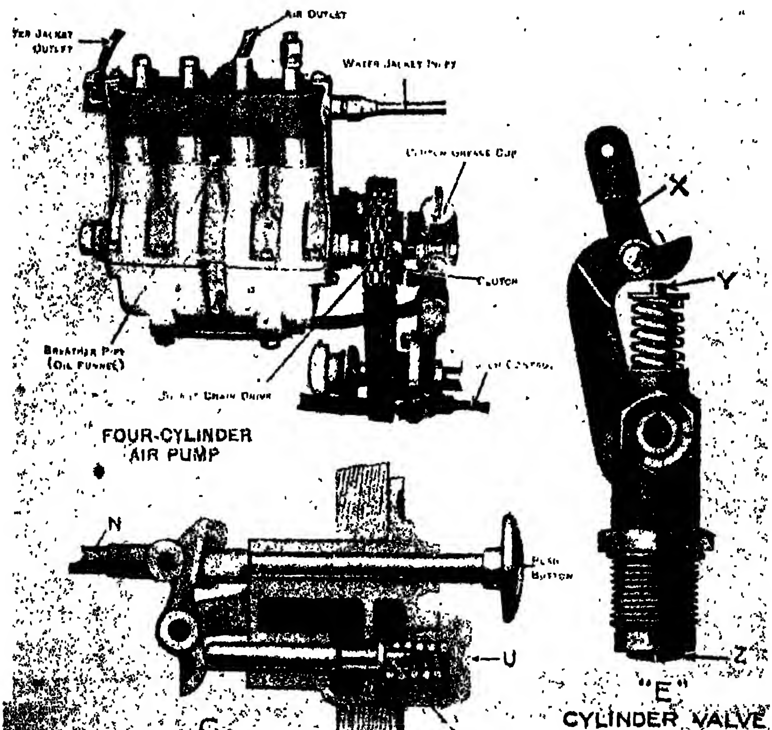


Fig. 283.—Some Important Components of Early Chalmers Air Starting System.

the distributor is practically the same as that of an ignition timer, its purpose being to distribute the air to the cylinders of the engine only in the proper firing order. All the while that the engine is running and the car is in motion the air pump is functioning unless thrown out of action by an easily manipulated clutch control lever. When it is desired to start the car a starting valve is opened which permits the air to flow to the top of the distributor, and then through a pipe to the check valve on top of the cylinder about to explode. As the air is going through under considerable pressure it will move the piston down just as the explosion would, and start the engine rotating. The inside of the distributor rotates and directs a charge of air to the cylinder next to fire. In this way the engine is given a number of revolutions, and finally a charge of gas will be ignited and the engine start off on its cycle of operation. One of the advantages of the air starter system is that a source of air is provided for blowing up tires.

The general arrangement of the Chalmers air starter was practically the same as that depicted. Some of the components were of different construction. Instead of being driven by enclosed gearing the air pump was operated through a silent chain from the pump shaft, as shown in the upper left hand corner, Fig. 283. In this air pump the cylinders were water jacketed in order to prevent overheating. The construction of the dash push valve is clearly shown at C. This member not only serves to admit air to the center of the distributor, but also opens the cylinder starting valves to permit the air to flow into the cylinder. The starting valve construction is clearly shown at E, this consisting of a simple fitting adapted to be screwed into the cylinders and communicating with the interior of the combustion chamber. The bell crank X was used to depress the valve stem Y, and thus provide communication between the air distributor and the combustion chamber interior. As the distributor was one of the important parts of all air-starting systems, that used on the Chalmers car when equipped with the air starter is shown at Fig. 284. By referring to the sectional view at the right of the illustration it will be apparent that its function is practically the same as that of a

primary timer or secondary distributor of a magneto, except that instead of distributing electrical energy a blast of air was directed to the cylinders in the proper firing order. The rotating distributor disc is provided with one slot which registers consecutively with the openings to which the pipes running to the various cylinders were fastened. About the only trouble with an air-starting system was faulty check valve action or leaks in the pipe line or distributor which permitted the escape of air. If no air pressure was supplied to the tank the pump was at fault. This may be easily determined on inspection; the same troubles should be looked for as described for the air pressure pump sometimes used in connection with the pressure system of fuel supply.

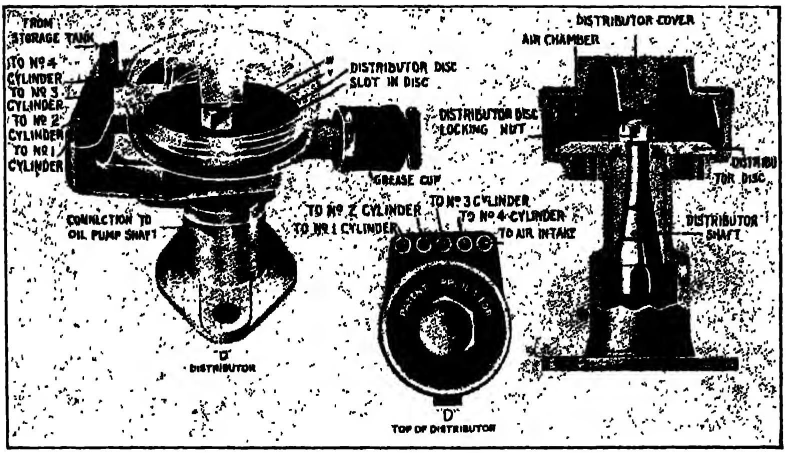


Fig. 284.—Showing Construction of Distributing Mechanism Employed with Air Starting System.

Pres-to-lite Primer.—Where a car is equipped with a Pres-to-lite gas tank it is possible to secure easy starting by hand cranking, and even to run the engine on acetylene gas in an emergency if the gasoline supply fails by using a simple priming fitting shown at Fig. 285. The outfit consists of an automatic reducing valve attached to the gas tank, a pipe line running to the dash, and a push valve so mounted that acetylene gas may be admitted into

the inlet manifold through a pipe running from the push valve to the intake member. As shown at A, a simple lever is rigged up so the push button may be operated from the front of the car. At B the push button is worked by the foot. The arrangement of the parts is clearly shown in the view at the bottom of the illustration. It is said that a properly charged gas tank will run a 25 H. P. motor from ten to twelve miles if the gasoline supply should fail. The reason the acetylene gas provides easy starting is that it is very inflammable and does not need to be vaporized as the liquid fuel does. The gas primer is of special value when used in connection with mechanical starters of various kinds. Before depressing the push button it is necessary to open the main shut-off valve incorporated with the push button assembly on the dash. This permits the gas to flow from the automatic pressure regulator to the body of the device where the push button valve provides access with the pipe running to the intake manifold. Obviously this priming system can be used only with cars equipped with a gas tank. On the modern electrically lighted and started cars the gas tank will be unnecessary, and is not apt to be used. However, the gas tank would probably be applied for lighting purposes on cars equipped with air starters, and on these models it would be of particular advantage inasmuch as the tendency of the air current passing to the cylinders is to retard prompt vaporization of the fuel sucked in from the carburetor, the rich acetylene gas would provide a rich mixture, and would enable the engine to run for a long enough period to permit the explosion to heat up the cylinders enough so the gasoline would vaporize promptly.

Electric Starter Forms.—Electric lighting, cranking and ignition systems for motor cars are of such recent development that it is not possible to describe all systems used for this purpose. Not only do the individual systems vary in detail, but the components of the same system are often of different construction when used on cars of different makes. The standard equipment must include three component parts, namely, the generator which is driven by the engine and which produces electric current to keep the storage battery charged, and the starting motor which is in

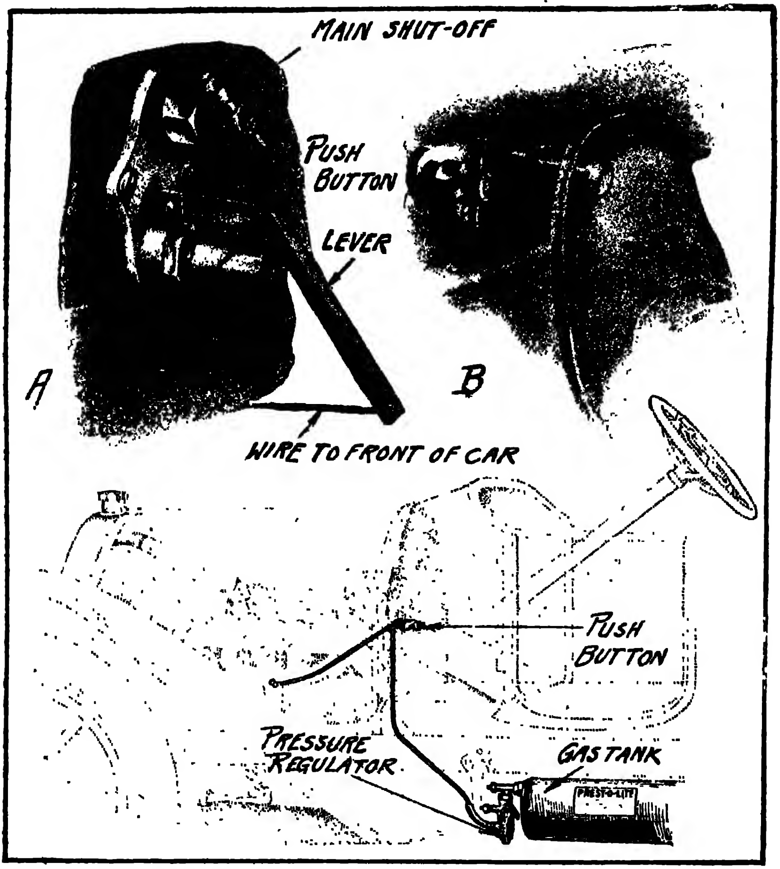


Fig. 285:—Showing Method of Utilizing Pres-to-lite Gas Tank to Facilitate Starting the Automobile Power Plant.

mechanical connection with the engine and in electrical connection with the storage battery when it is desired to turn the engine over for starting. If the motor and generator are combined in one instrument the starting system is known as a one unit type. If the motor is one appliance and the generator another, the system is said to be a two unit system. Each of these has advantages, and both forms have demonstrated that they are thoroughly prac-

tical. In addition to the three main items enumerated, various accessories such as switches, ammeters, connectors, wiring, protective circuit breakers, automatic current regulators, etc., are necessary for the convenient distribution and control of the electric current. The arrangement of the parts of a typical one unit system in which the motor-generator is used only for starting and lighting is shown at Fig. 286. This shows the location of the

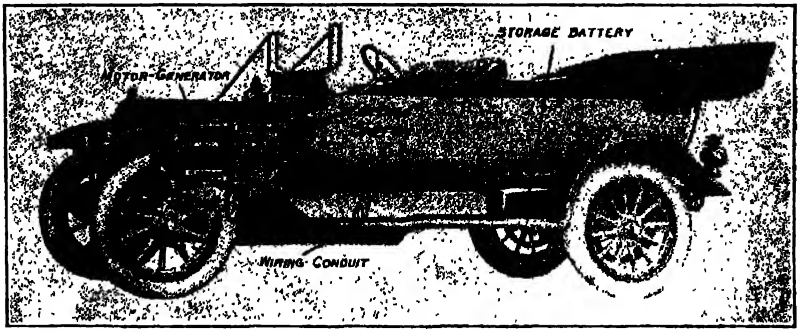


Fig. 286.—Side View of Typical Automobile Showing Application of Entz One Unit Starting and Lighting System.

various parts in their relation to the other components of the motor car. The motor generator is mounted at the side of the engine, and is driven by the magneto drive shaft when used as a generator, and serves to drive the engine through this means when it is used as a motor. The ignition current is supplied from independent source, a high tension magneto. The starting switch and that controlling the lighting system are placed on the dash, while the storage battery is carried under the floor of the tonneau. This system, which is known as the Entz, will be described more in detail in proper sequence.

The elements of a one unit system are shown in diagram form at the left of Fig. 287. It will be observed that the armature carries two commutators, one of which is used when the armature is driven by the engine and when the device serves as a current generator, the other being employed when the operating conditions are reversed and the electrical machine is acting as a motor to turn

over the engine crankshaft. When the device is driven as a generator the small sliding pinion on the short end of the shaft is out of engagement with the spur gear cut on the flywheel exterior. When it is desired to start the engine the spur gear is meshed with the member cut on the flywheel and the current from the storage battery is directed to the windings of the electric machine which becomes a motor and which turns over the engine crankshaft. When the device is working as a generator the current that is developed goes to the storage battery, and from that member to the various current consuming units.

Sometimes the motor and generator are combined in one casing and the system so provided is erroneously called a "one unit"

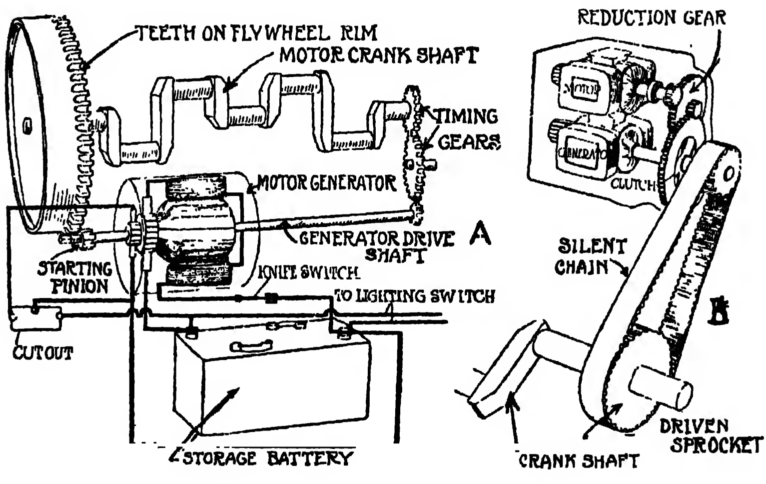


Fig. 287.—Diagram Defining Application of One and Two Unit Motor Starting Systems.

system. This construction is shown at the right of Fig. 287. In reality such a system is a two unit system, because the electrical machines are uni-functional instead of performing a dual function as does the combined-motor-generator at the right of the illustration. The wiring is shown in simplified form and should be easily followed by any repairman. The parts of a two unit start-

ing and lighting system are shown at Fig. 288. This system is sometimes called a "three unit" system, on account of having a source of independent current supply for ignition purposes. As will be observed, the generator is driven from the motor crankshaft by silent chain connections, one of the terminals passing through the cut-out device and to the storage battery, the other terminal running directly to the storage battery terminal having a short by-pass or shunt wire attached to the cut-out. All the time that the engine is running the generator is delivering electricity to the storage battery.

It will be observed that the storage battery is also coupled to the lighting circuits which are shown in a group at the right of

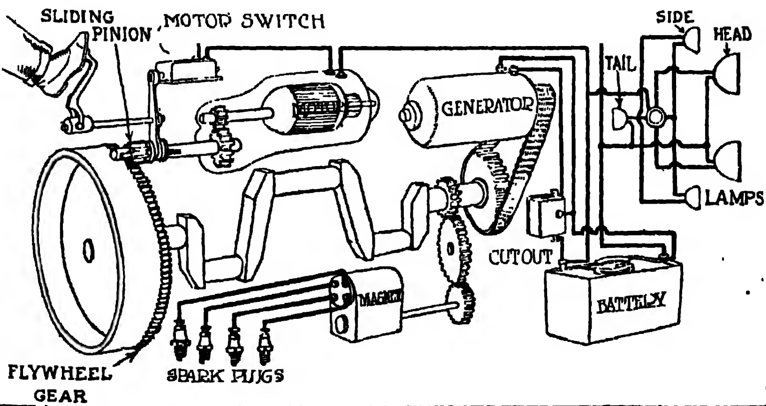


Fig. 288.—Diagram Showing Components of Three Unit Starting, Lighting and Ignition Systems.

the illustration, and to the electric starting motor as indicated. One of the storage battery terminals is joined directly to the switch terminal by a suitable conductor, the other goes to one of the terminals on the starting motor, while the remaining terminal of the starting motor goes to the switch. In this system, when the small sliding pinion is meshed with the flywheel gear, the switch is thrown on simultaneously, and the current that flows from the storage battery through the windings of the starting motor rotates

the engine crankshaft by means of reduction gears shown. As soon as the engine starts the foot is released and a spring pulls the switch out of contact, and also disengages the sliding pinion from the flywheel gear.

The actual appearance of a motor fitted with a two unit motor starting and lighting system is shown at Fig. 289. It will be

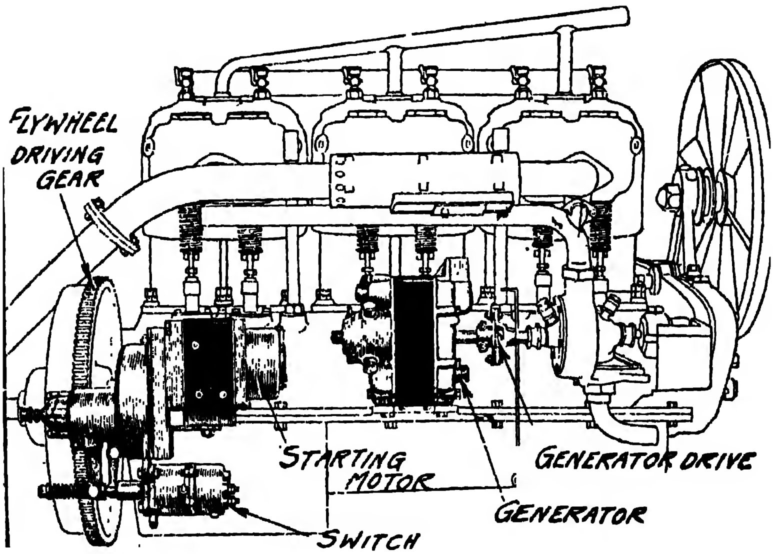


Fig. 289.—Method of Attaching Starting Motor and Generator of Typical Three Unit System on Six Cylinder Engine.

observed that the generator is driven from the pumpshaft extension by a leather universal joint, while the starting motor is mounted at the back end of the crankshaft in such a position that the concealed sliding pinion may be brought into engagement with the flywheel driving gear. The interlock between the starting switch and the pinion shifting means is also clearly shown. Electrical starting systems may be operated on either six- or twelve-volt current, the former being generally favored because the six-volt lamps use heavier filaments than those of high voltage, and are

not so likely to break due to vibration. It is also easier to install a six-volt battery, as this is the standard voltage that has been used for many years for ignition and electric lighting purposes before the starting motors were applied.

In referring to a system as a one unit system of lighting, starting and ignition, one means that all of these functions are incorporated in one device, as in the Delco system described in the chapter on ignition. If one unit is used for generating the lighting and starting current, and also is reversible to act as a motor, but a separate ignition means is provided such as a high tension magneto, the system is called a "two unit" system. The same designation applies to a system when the current generating and ignition functions are performed by one appliance, and where a separate starting motor is used. The three unit system is that in which a magneto is employed for ignition, a generator for supplying the lighting and starting current, and a motor for turning over the engine crankshaft. Before describing the individual systems it would be well to review briefly the various components common to all systems.

The generator, as is apparent from its name, is utilized for producing current. This is usually a miniature dynamo patterned largely after those that have received wide application for generating current for electric lighting of our homes and factories. The generators of the different systems vary in construction. Some have a permanent magnetic field, while others have an excited field. In the former case permanent horseshoe magnets are used as in a magneto. In the other construction the field magnets, as well as the armature, are wound with coils of wire. In all cases the dynamo or generator should be mechanically driven from the engine crankshaft either by means of a direct drive, by silent chain, or through the medium of the timing or magneto operating gears. Belts are apt to slip and are not reliable.

All the current produced by the generator and not utilized by the various current consuming units such as the lamps, ignition system, electric horn, etc., is accumulated or stored in the storage battery, and kept in reserve for starting or lighting when the engine is not running or for lighting and ignition when the car

is being run at such low speed that the generator is not supplying current. Storage batteries used in starting systems must be of special design in order to stand the high discharge and to perform efficiently under the severe vibration and operating conditions incidental to automobile service. The storage battery may be installed on the running board of the automobile, under the body, or under the front or rear seat, the location depending upon the design of the car and the degree of accessibility desired. The best practice is to set the storage battery in a substantial carrying case held by rigid braces attached to the frame side and cross members. If the battery should be set under the tonneau floor boards, a door must be provided in these to give ready access to the battery.

The starting motor, which takes the place of the common hand crank, is operated by current from the storage battery, and the high speed armature rotation is reduced to the proper cranking speed by reduction gears of the different forms to be described in proper sequence. The construction of the starting motor is practically the same as that of the dynamo, and it operates on the same principle, except that one instrument is a reversal of the other.

In order to secure automatic operation of a lighting and starting system several mechanical and electrical controls are needed, these including the circuit breaker, the governor, which may be either mechanical or electrical, and the operating switches. The circuit breaker is a device to retain current in the storage battery under such conditions that the battery current is stronger than that delivered from the generator. If no circuit breaker was provided the storage battery could discharge back through the generator winding. The circuit breaker is sometimes called a "cutout." The circuit breaker is usually operated by an electro magnet, and may be located either on the generator itself or any other convenient place on the car, though in many cases the circuit breakers are usually mounted on the back of the dashboard. This device is absolutely automatic in action and requires but little attention.

The governors are intended to prevent an excessive output of current from the generator when the engine runs at extremely high speed. Two types are used: one mechanical, operated by

centrifugal force, and the other electrical. The former is usually a friction drive mechanism mounted on the generator shaft which automatically limits the speed of the dynamo armature to a definite predetermined number of revolutions per minute. The maximum current output is thus held to the required amount independently of the speed at which the car is being driven. The use of this device minimizes the possibility of overheating the generator overcharging the battery at high car speeds. The electrical system of governing does not affect the speed of the armature, but controls the output of the generator by means of armature reaction and a reversed series field winding. The governors usually permit a maximum generator output of from ten to twelve amperes, though the normal charging current is less than this figure.

In practically all systems an amperemeter is mounted on the dash so that it can be readily inspected by the driver, this indicating at all times the amount of current being produced by the dynamo or drawn from the battery. If the indicating needle of the amperemeter points to the left of the zero point on the scale, it means that the battery is furnishing current to the lights or other current consuming units or discharging. When the needle points to the other side of the scale, it means that the generator is delivering current to the battery which is charging it, the amount of charge or discharge at any time can be read from the scale on the face of the amperemeter. Some of these instruments have the words "charge" and "discharge" under the scale in order to enable the operator to read the instrument correctly.

Another important element is the lighting switch, which is usually mounted at some point within convenient reach of the car driver. This is often placed on an instrument board on the back of the cowl in connection with other registering instruments. As ordinarily constructed, the switches are made up of a number of units, and the wiring is such that the head, side and tail lamps may be controlled independently of each other. For simplicity and convenience of installation, the switch is usually arranged so that all circuits are wired to parallel connecting members or "busbars" placed at the rear of the switch. In some cars, as the Overland 80 model, the switch units are placed on the steering

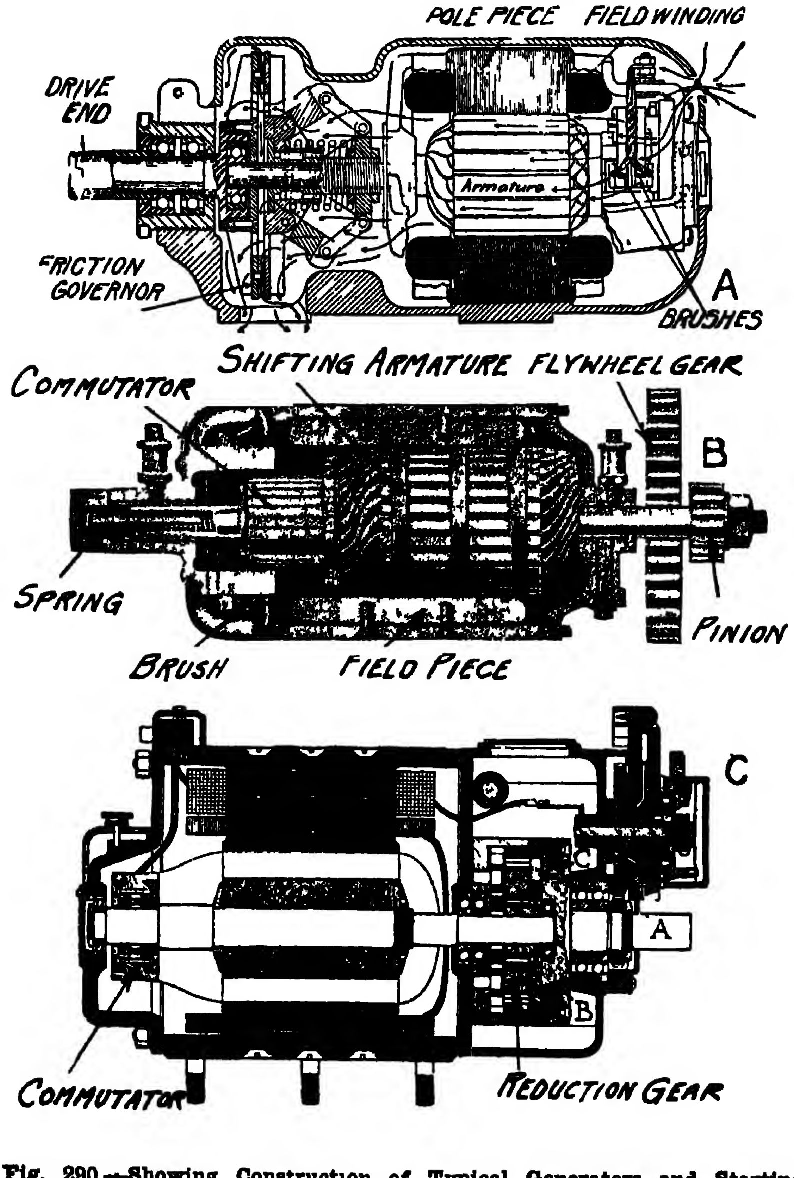


Fig. 290—Showing Construction of Typical Generators and Starting Motors

column. As but little current passes through the lighting switch the contacts are not heavy in construction as are those of the starting switch.

The function of the starting switch is to permit the current to flow from the storage battery to the starting motor, when it is necessary to start the car. It is arranged usually so as to be readily operated by the foot and is nearly always installed at some convenient position on the toe board of the car. As we have previously shown, the starting switch is often interlocked with the starting motor gearing so that the operation of engaging the gear with the flywheel and of turning on the current to the starting motor are accomplished simultaneously. The lighting and motor starting wiring systems are independent of each other, and may be easily found as that used to convey the high amperage starting current is of heavy round single conductor cable, while the lighting wiring is usually a light multiple strand cable. In order to prevent chafing and depreciation of the insulation the wiring is often protected by conduits of a flexible metal tubing, and the terminals are extremely heavy and well adapted to resist the vibration which is unavoidable in automobiles.

Generators and Starting Motors.—Essentially there is not much difference in construction between a starting motor and a generator as the principles upon which they operate are practically the same. A machine that is capable of delivering current in one direction when driven by mechanical power will produce mechanical energy if electrical current is passed through the winding in a reverse direction. The construction of typical starting motors and generators may be readily understood if one refers to the illustrations at Fig. 290. That at A is one form of the Gray & Davis governed dynamo, which is of the limited armature speed type. The power is directed to the driving member of a friction clutch which turns the generator armature by means of friction contact with a disc attached to but slidably mounted on the armature shaft. This plate is held in contact by a coil spring. A pair of hinged governor arms are attached to the driven clutch plate, while the other ends are attached to a rotating spider member fastened on the dynamo armature shaft. When the speed in-

creases beyond a given point the governor weights fly out, due to centrifugal force, and reduce the amount of frictional adhesion between the clutch members in proportion as the armature shaft

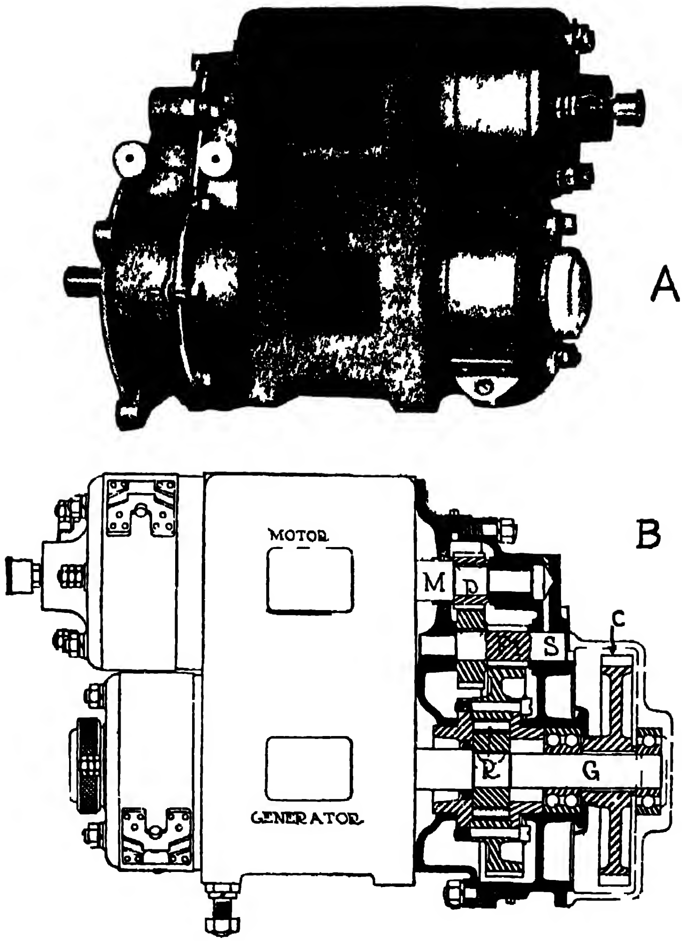


Fig. 291—The Disco Two Unit Outfit Having Motor and Generator Mounted in Common Carrying Case, the Motor Being Placed Above the Generator

speed augments, until the point is reached where there is no frictional contact between the parts of the clutch and the driving plate is turning at engine speed, while the driven member that imparts motion to the armature is gradually slowing down and permitting the tension of the coil spring to overcome that force produced by rapid rotation, and to bring the discs in contact again for just a sufficient length of time to enable the armature to maintain its rated speed even if the engine is running faster than normal.

A typical starting motor, which is of the Rushmore design, is shown at B. As will be evident, this is practically the same in construction as the generator shown above it, as far as essentials are concerned, except that no governor is provided and the armature shaft is fitted with a small spur pinion designed to engage with the spur gear on the engine flywheel. No mechanical interconnection is necessary between the drive pinion and the electrical starting switch. As soon as the current flows through the armature of the motor it will move that member laterally and automatically engage the pinion of the flywheel gear. As soon as a starting switch is released, a coil spring will push the starting motor armature back again in the position shown in the illustration, and thus automatically bring the pinion out of mesh with the flywheel gear. In order to obtain a sliding feature this motor armature shaft is mounted on plain bearings instead of ball bearings, which are standard equipment on practically all machines of this nature.

The device outlined at Fig. 290, C, shows the construction followed when the ignition function is combined with a current generator and starting device having the three functions performed by one instrument. The general construction is the same as in the device previously outlined. The drive-shaft of the device is adapted to be attached to the engine by direct mechanical means. When the device is used as a current generator, the armature is driven by the shaft, whereas if the device is used as a motor the armature drives the shaft A through a planetary reduction gearing and roller clutch. Regardless of whether the device is used as a motor or generator, the distributor for ignition purposes is driven

in the same direction, and at the proper speed to insure ignition as it is driven directly from shaft A, which turns at crankshaft speed.

An example of a double deck combined instrument in which the generator is carried in the lower portion of the casing and the starting motor at the upper part is clearly shown at Fig. 291. The view at A shows the external appearance while the partial section at B makes clear the arrangement of the reduction gearing and roller clutch. This type is meeting with favor because it is mounted easily, and also on account of the simple mechanical connection to the engine. While the two units are electrically separate, i.e., each having its own field and armature, it may be considered as one unit mechanically. The double deck instrument shown is designed for application to the side of a gasoline engine connecting by chain or gearing to the pump or magneto drive shaft. It should be noted that this chain or gear is the only connection between the machine and the engine, and that it is used not only for transmitting the engine energy to the generator, but also acts to transmit the power from the starting motor to turn the engine crankshaft when it is desired to start the power plant. It will be apparent that in a combined instrument of this type that it is necessary to have a fairly low gear ratio between the motor and the engine in order to reduce the high speed of the motor armature rotation to a speed low enough to turn over the engine crankshaft. At the other hand, once the power plant is started the generator armature must turn at a slower speed than that of a starting motor, and if it is run from the pump shaft or magneto drive shaft it will turn fast enough to generate the proper quantity of electricity. The starting motor, however, must be geared down in order that it may exert the starting torque through the high leverage furnished by the reduction gear. The motor occupies the upper position as shown at B, Fig. 291, and carries a pinion P keyed to the end of its armature shaft M. This pinion transmits the drive to an intermediate shaft, S, which in turn drives the large gear forming the outer casing of an overrunning roller clutch R. The inner or driven member of this clutch is mounted rigidly on the armature shaft G of the

generator and carries the drive through to the outer chain gear C when cranking the engine. As soon as the engine explodes and the speed runs above that represented by the starting motor at the roller clutch the latter comes automatically out of action, thus permitting the generator to obtain its power in the normal way through

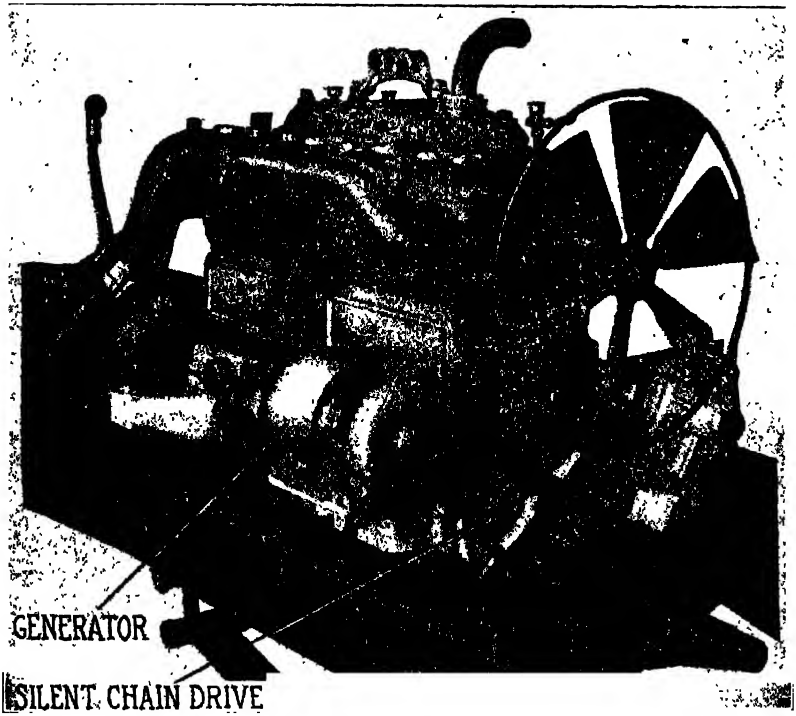


Fig. 292.—Method of Driving Gray & Davis Generator by Silent Chain from Engine Crankshaft.

the chain wheel C attached to the dynamo shaft G. The motor armature above comes to rest as soon as the starting switch is released. The generator of this device has its output controlled by a combination of armature reactions and a bucking coil, while the battery is protected from discharging back through the generator by a simple magnetic contact breaker or cut-out.

Generator Driving Methods.—When electric lighting was first applied to automobiles it was not considered necessary to drive the generators by positive connection, and the early devices were furnished with pulleys for flat or V belt drive. At the present time it

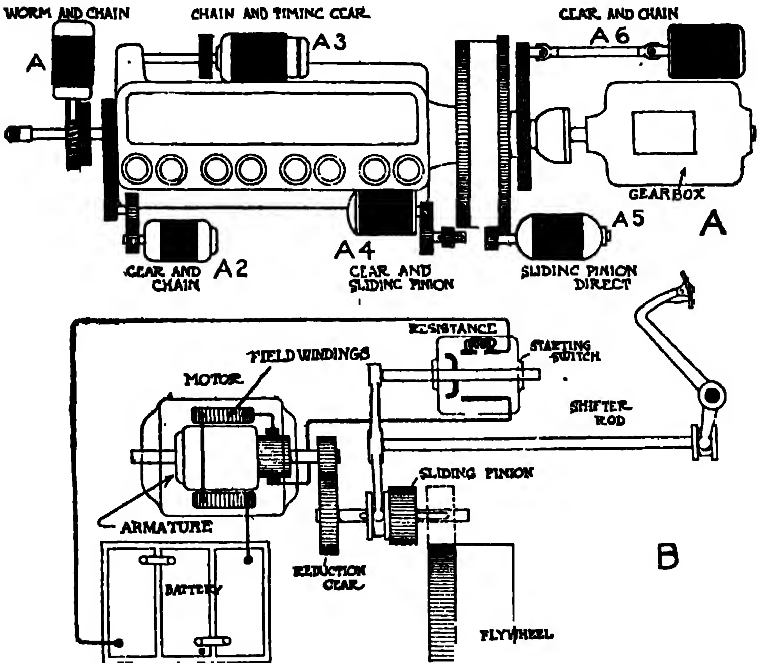


Fig. 293.—Diagram Showing Methods of Transmitting Power of Starting Motor to Power Plant, Also Simplified Diagram Showing Interconnected Starting Switch and Motor Starting Gear.

is considered highly important to provide a positive mechanical connection that will not slip between the generator and the engine crankshaft. The common systems where the generator is a separate unit from the starting motor and in those forms where the starting and generating functions are combined, involve a connection with the motor crankshaft through some form of gearing. As will be apparent in Fig. 289, the generator is driven by means of

universal joint connections with an extension of the pump shaft. The motor crankshaft imparts its power through the camshaft timing gear to the small pinion utilized in driving the water pump. In the generator application shown at Fig. 292 the armature is rotated by silent chain connection with a gear on the motor crankshaft. There is not the diversity of drives for the generator as there is in the methods of connecting the starting motor to the end of the crankshaft.

Starting Gearing and Clutches.—In order to show the variety of driving means used in connecting the starting motor to the work of turning over the engine crankshaft, the leading systems have been grouped in one illustration at the top of Fig. 293. Starting from the front of the motor, the first method shown is by means of a worm gear initial or primary reduction and chain connection from the worm-driven shaft to the motor crankshaft. In some cars the worm reduction is used having the starting motor mounted at the side of the change speed gear box instead of attached to the motor crankshaft. The reduction in speed may be by means of the spur gears and chain, as shown at A-2, or by a chain to a shaft connected with the timing gear, as in A-3. The method at A-4 is a very popular one, including a reduction to an intermediate shaft, which carries a sliding pinion designed to engage the gear on the flywheel rim. The method at A-5 is used with the Rushmore starter, the pinion being brought into direct engagement with the gear on the flywheel by the axial movement of the armature when the current is supplied to the field winding. The method at A-6 permits of attaching the starting motor securely to the frame side member at a point near the gear box, where it will be out of the way and not interfere with the accessibility of the power plant. When mounted in this manner the drive is by a double universally jointed shaft to a small silent chain sprocket, which connects to a much larger member attached to the engine flywheel or crankshaft.

The complete system shown at Fig. 293, B, is the most popular of all that have been used. This shows the application of the starting motor, outlined at A-4. The mechanical interlock between the sliding pinion on the intermediate shaft and the starting switch is clearly shown. Before the pinion engages the gear on the fly-

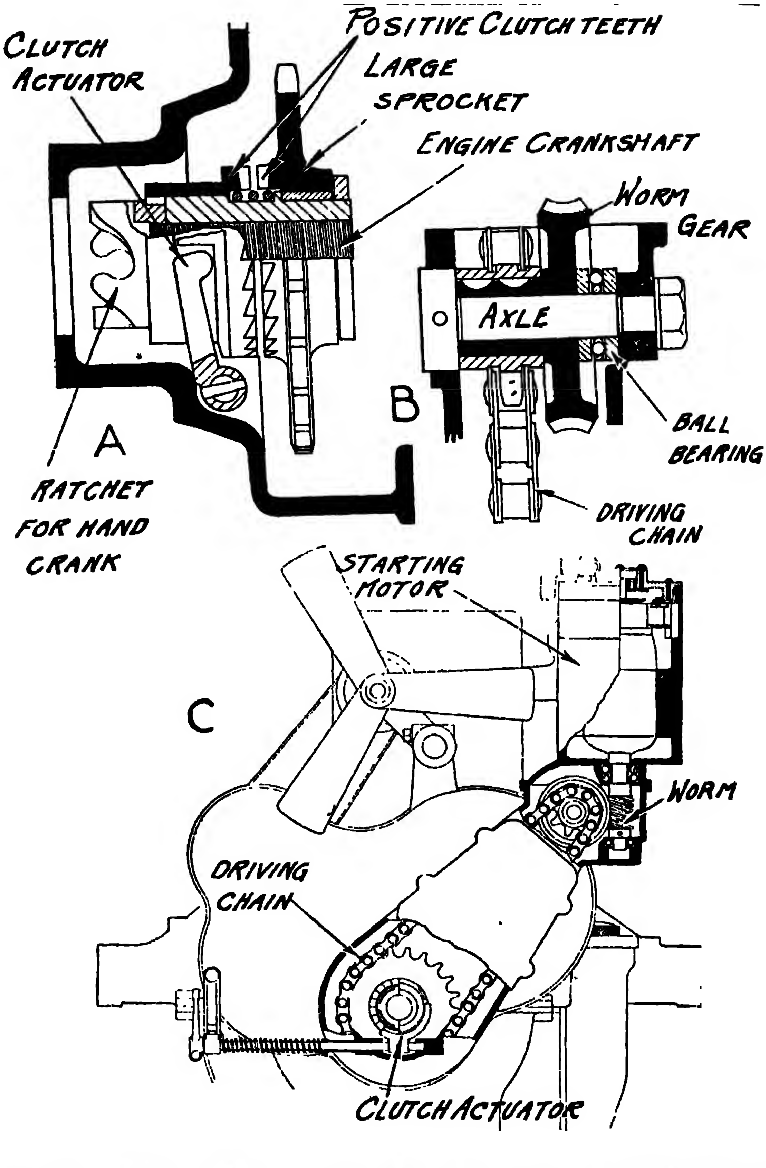


Fig. 294.—Method of Mounting Starting Motor Having Speed Reduction Through Worm Gears and Roller Chains.

wheel rim the switch makes contact, but owing to the resistance interposed in circuit the motor will turn slowly to permit of more ready engagement of the sliding pinion. As soon as the pinion is fully engaged with the large gear the resistance is cut out and the motor draws what current it needs from the storage battery, this being enough to produce the torque necessary to turn over the engine flywheel and the crankshaft to which it is attached at such speed as will produce prompt starting.

The actual application of the system, shown at A-1, Fig. 293, is outlined at C, Fig. 294. It will be observed that the starting motor is attached to the side of the engine in a vertical position and that it drives the intermediate shaft by means of a worm on the motor armature, which engages with a worm gear on the intermediate shaft, which also carries the driving sprocket, as shown at B. A further reduction in speed is obtained owing to the difference in size of the small sprocket on the intermediate shaft and that attached to the clutching member normally revolving free on the motor crankshaft. It will be seen that the motor armature is supported on ball bearings, and that one of these, backing the worm, is a double row form capable of sustaining both the end thrust and radial load imposed by the driving worm. In order to resist the end thrust on the worm gearing successfully a ball thrust bearing is used, as shown at B. When it is desired to start the motor the clutch actuator, which is shown in the diagram at A, is pushed in until it engages the ratchet teeth cut on the face of the large sprocket. When the sprocket turns it must turn the engine crankshaft in the same direction, but just as soon as the engine runs faster than the large sprocket the clutching action will be released automatically by the ratchet teeth being thrown out of engagement. If it is necessary to start the engine by means of a hand crank this may be done by inserting the starting crank in the starting ratchet provided on the extreme end of the crankshaft. The large sprocket is normally free and the engine crankshaft turns without producing a corresponding movement of the sprocket member. The general arrangement of the parts is so clearly shown that no further description will be necessary.

The construction of a typical overrunning clutch is clearly

shown at Fig. 295. The electric starting motor is secured to a base on the crankcase of the gasoline engine and the motor power is imparted through the medium of the small gear F carried by the armature shaft. This drives gear E, which turns at a lower speed on account of being larger, and that in turn engages with gear D, which is still larger in diameter. The small pinion C, which turns much slower than the motor pinion F, meshes with the large gear

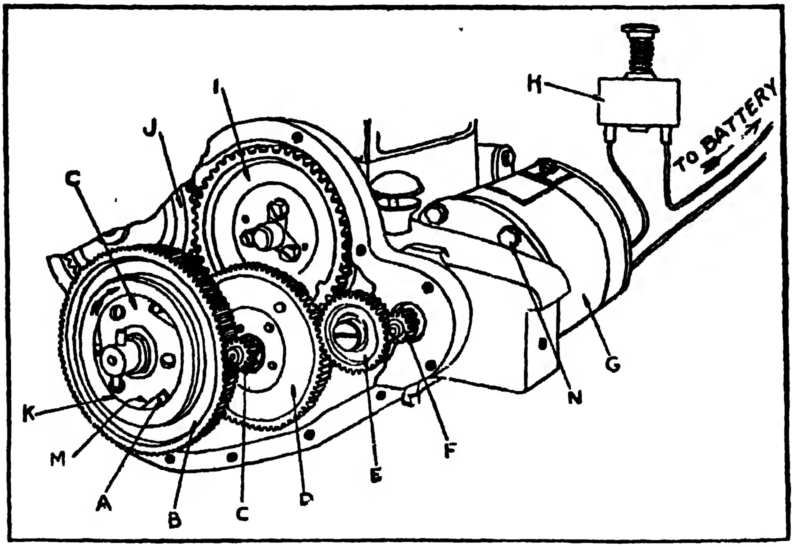


Fig. 295.—Defining Construction of Typical Roller Clutch.

B attached to the clutch body. The use of this gearing provides a reduction of 40 to 1, which means that gear F must make 40 revolutions to one of the clutch body.

The ratchet or driven member of the overrunning clutch L is pinned to the engine crankshaft and revolves with it when the motor is operating, rotating inside of the gear B, having a bearing at K and turning in the direction of the arrow. The member L has three flat surfaces, M, cut at an angle to the inside of the gear B. On each of these a hardened steel roller, A, is held inside of the gear by a light spring and against the flat surface of the member

L. The roller travels with the clutch and runs free against the side of the gear B when the engine is in motion and when the starting gears are idle. As soon as the current is directed to the electric starting motor, the three rollers are bound between the clutch body and the ratchet member carrying them and the crankshaft is driven until such time as the engine speed increases sufficiently to overrun that of the member attached to the crankshaft.

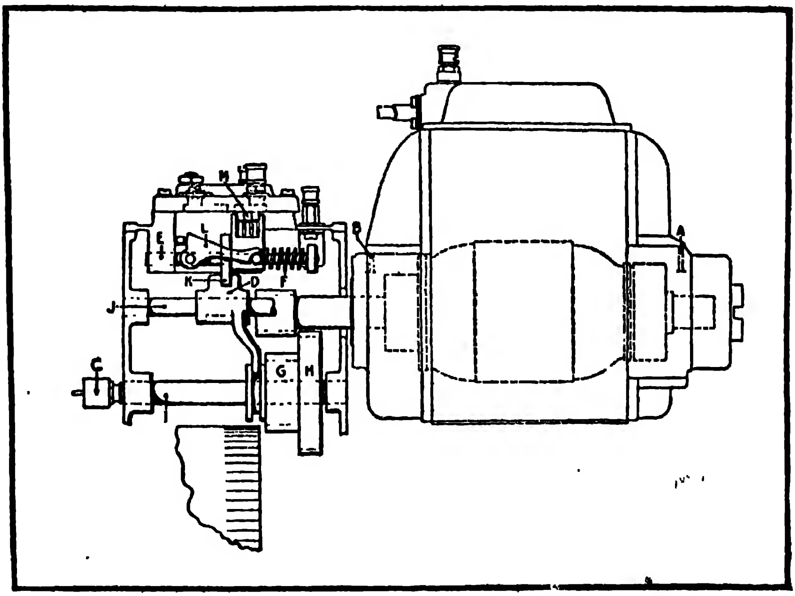


Fig. 296.—Showing Interconnection between Starting Switch and Intermediate Pinion of Delco System.

Overrunning clutches are not necessary in those systems in which the gears are moved into engagement, as in that shown at Fig. 296. In this the starting switch and the double shifting member, GH, are mechanically interconnected so that the starting switch will not be completely engaged until gearing is in mesh. The larger gear H of the sliding members meshes with that on the armature shaft, while the smaller of the pair, G, meshes with the flywheel. The arrangement of the parts outlined is used on the Cole

car. In the Hartford starting motor, which is shown at Fig 297, A, the clutch is of the friction type and is engaged automatically when the energy is passed through the motor winding to produce movement of the engine crankshaft. The reduction between the

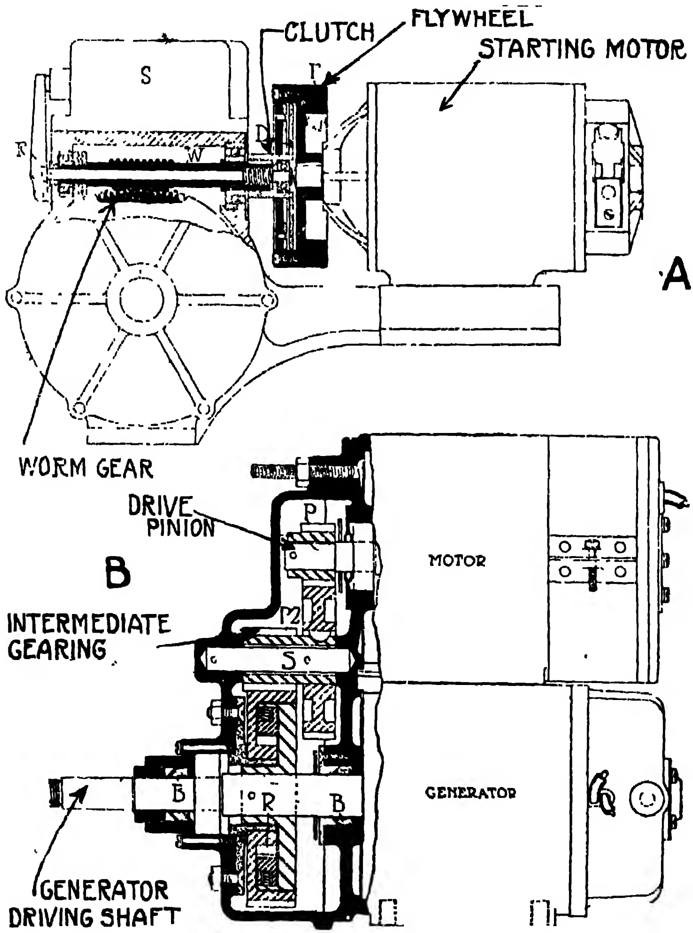


Fig. 297.—The Hartford Starting Motor Employing Worm Gear Reduction at A, Ward-Leonard Combination at B.

starting motor and the crankshaft is made by a worm and worm gear. When the switch pedal is depressed and the switch blades go into contact the same movement produces pressure on the end of the lever attached to R R, which transmits a strong pull on the friction clutch and thus connects the motor to the starting gear. The Ward Leonard combination is shown at Fig. 297, B. In this the motor is carried above the generator, and but one driving gear is needed to operate both the generator and to enable the starting motor to turn over the engine crankshaft. The speed reduction is by an intermediate gear shaft, the general operation being the same as that of the Disco starter, previously described.

Switches and Current Controlling Devices.—The various methods of operating the starting switch, which may be interconnected with the gearing to turn the crankshaft, are shown at Fig. 299. All of the methods of actuating the electric self-starter may be grouped into three main classes: one, by hand lever; two, by pedals, and three, by semi-automatic means. The method at A is used on some Paige-Detroit cars, a hand lever, A, attached to the steering column being used to make the mechanical interconnection between the clutch pedal and the starting gear mechanism. In order to safeguard the gearing of the starter the electrical connection cannot be effected until this mechanical interconnection is made. After the hand lever is thrown over in the proper position, depressing the clutch pedal suffices to permit the electrical connection to be made and the gasoline engine started. In the Hupmobile control, which is shown at B, a small auxiliary lever S is used to put the starter into gear. The view at D shows a small pedal which is employed to make the starting connection. This is the most popular system, especially when pedal is connected with the current-controlling switch, so that the full amount of current will not flow to the motor until the reduction gearing is completely engaged.

An example of the semi-automatic method which is used on the cars employing the Entz starter, namely, the Franklin, Chalmers and White, is shown at C. To put the starter in operation it is only necessary to move the handle H on the dashboard or other convenient position, where it may be readily reached with the hand or foot. This method is called the semi-automatic, because

the starter operates all the time until the gasoline engine is stopped by short circuiting the ignition. The first step is to throw the handle to the ignition point, and after closing the ignition switch, it is moved in the same direction until the storage battery has been connected to the starter generator. It is not necessary to touch the handle again until one desires to stop the engine, as moving the handle to the other extreme of its operating quadrant first opens the connection between the storage battery and the motor generator and then interrupts the ignition. With this starting system, if the motor should be stalled for any reason or slow down below its nor-

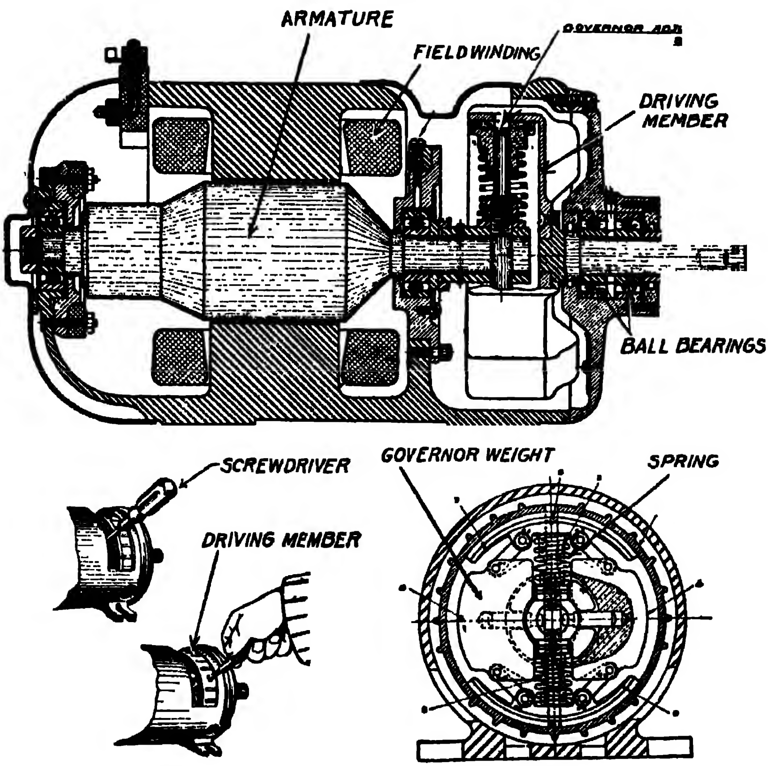


Fig. 298.—Method of Adjusting Governor of Gray & Davis Governed Dynamo.

mal cranking speed the starting motor-generator unit automatically changes from a generator to a motor and turns the gasoline engine crankshaft, making it practically impossible to stall the engine with this type of starter.

Owing to the large amount of current starting switches must carry, they are made much heavier in construction than lighting switches. They must be mechanically strong and the contact areas be sufficiently large to pass a current of from 40 to 200 amperes, depending upon the voltage of the starting system and the size of the engine to be turned over. If the contact points were not of large area they would be very soon burnt. There are two types of starting switches in common use, one has only a single contact and is used on those systems in which the motor is connected at once directly to the battery terminal. The other type of switch has two sets of contacts, the first one completing a circuit through a resistance, the second one cutting out this resistance and permitting the maximum current to flow. The Gray & Davis laminated switch, shown at Fig. 300, A, is a two-contact form. A movement of the switch actuator first engages the blades with the contacts E E, then the arched contact piece L makes a connection with the pieces C C to allow the maximum current to pass. With the switch shown at D, which is also of Gray & Davis manufacture, there are no starting gears, and the only necessary operation is to direct the current directly from the battery into the starting motor winding. The switch is set in the floor boards of the car and is operated by the push rod P, which terminates with a button. The contacts C and O are circular in form and their free ends are turned away from each other so they may slip down over the members R and S, which are set in the insulating piece B. As soon as the pressure of the foot is released a spring returns the push button P and the electric circuit is broken.

The switch used on some of the Delco systems is shown at C. In the latest form the motor generator has two independent windings, both on the field and the armature. If the current from the battery is directed into the generator end the machine acts as a shunt motor and the armature rotates at a moderate speed. If the starting gearing will not mesh immediately when brought together

a starting button on the dashboard enables the operator to pass the current through the generator winding, this causing the armature to turn over and facilitating meshing of the gearing. The main starting switch has only two points. In the off position the starter

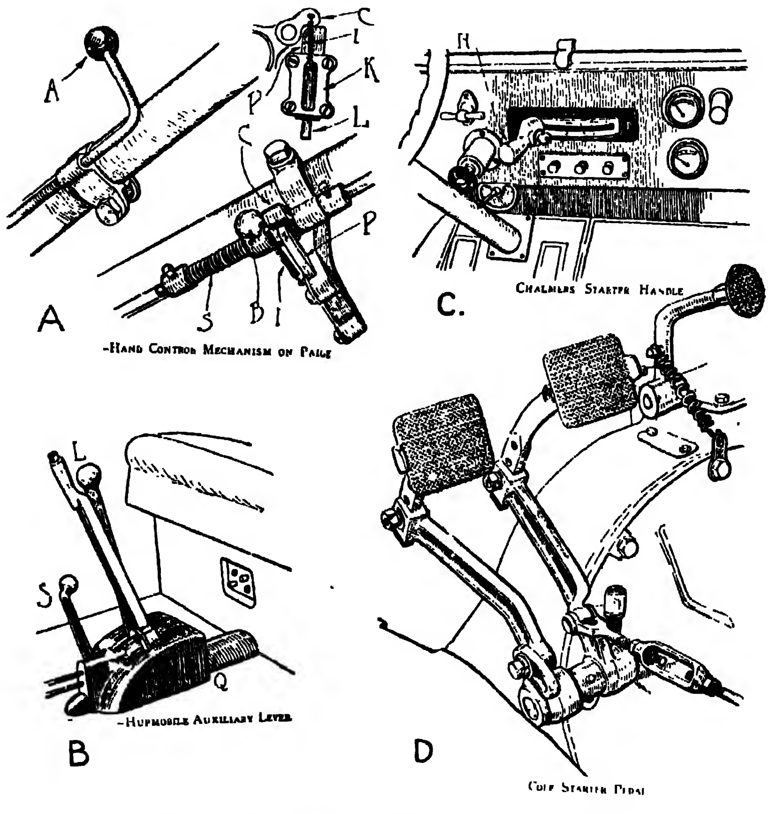


Fig. 299.—Conventional Method of Engaging Starting Gearing.

is connected directly to the battery terminal. An auxiliary contact on the starting switch breaks the circuit through the generator end and stops the current flowing when the device is used as a starting motor. A heavy copper bar is moved across the face of the contacts B, E and F, the switch normally connects E and F, a feature

which is necessary because of the dual functions of the combined motor generator. When the copper bar is moved to the left contacts B and F are brought into full electrical connection with one another and the entire battery current then flows to the motor. The contact pieces are molded into a piece of insulating material. The contact bar is pressed against them by means of springs.

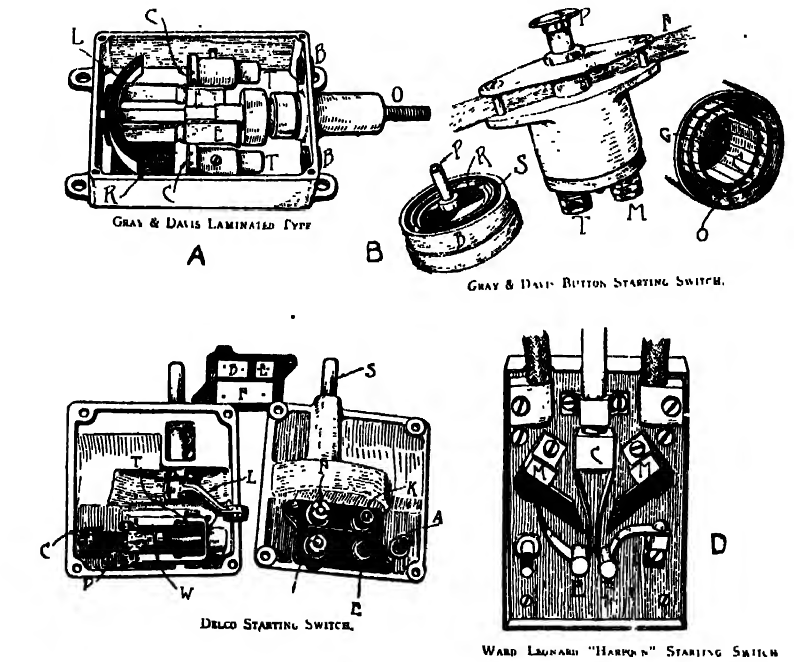


Fig. 300.—Showing Construction of Typical Motor Starting Switches.

Another form of laminated spring switch, which is known as the harpoon type, is shown at B. This is of Ward Leonard design. It is designed for use with a starter having flywheel gear drive, therefore it provides two contact points. The first contact with resistance in circuit is secured when the fingers C contact or make connection with the plugs E and F. Further movement of the switch short circuits the resistance by closing the main laminated con-

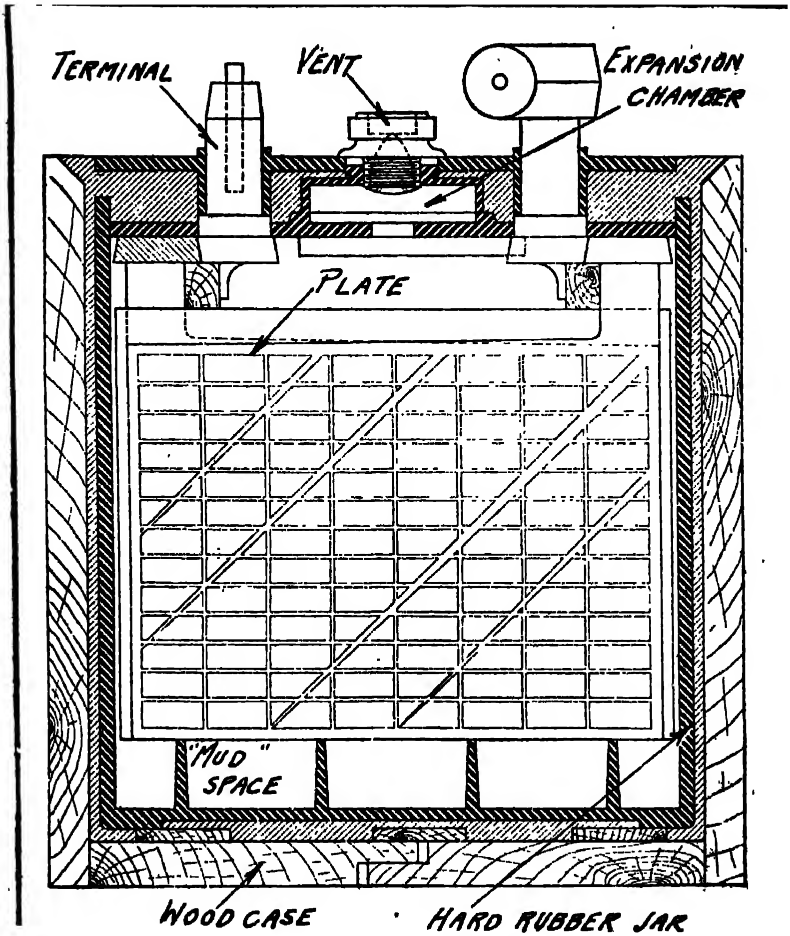


Fig. 301.—Sectional View, Showing Construction of High Capacity Storage Battery Intended for Use With Motor Starting and Lighting Systems.

tacts M M. These allow for considerable latitude of movement. The entire switch is built up on a piece of slate as a base and the resistance coils of wire are placed in the back of this base piece." The switches shown may be considered representative design, though the construction varies with practically every starting sys-

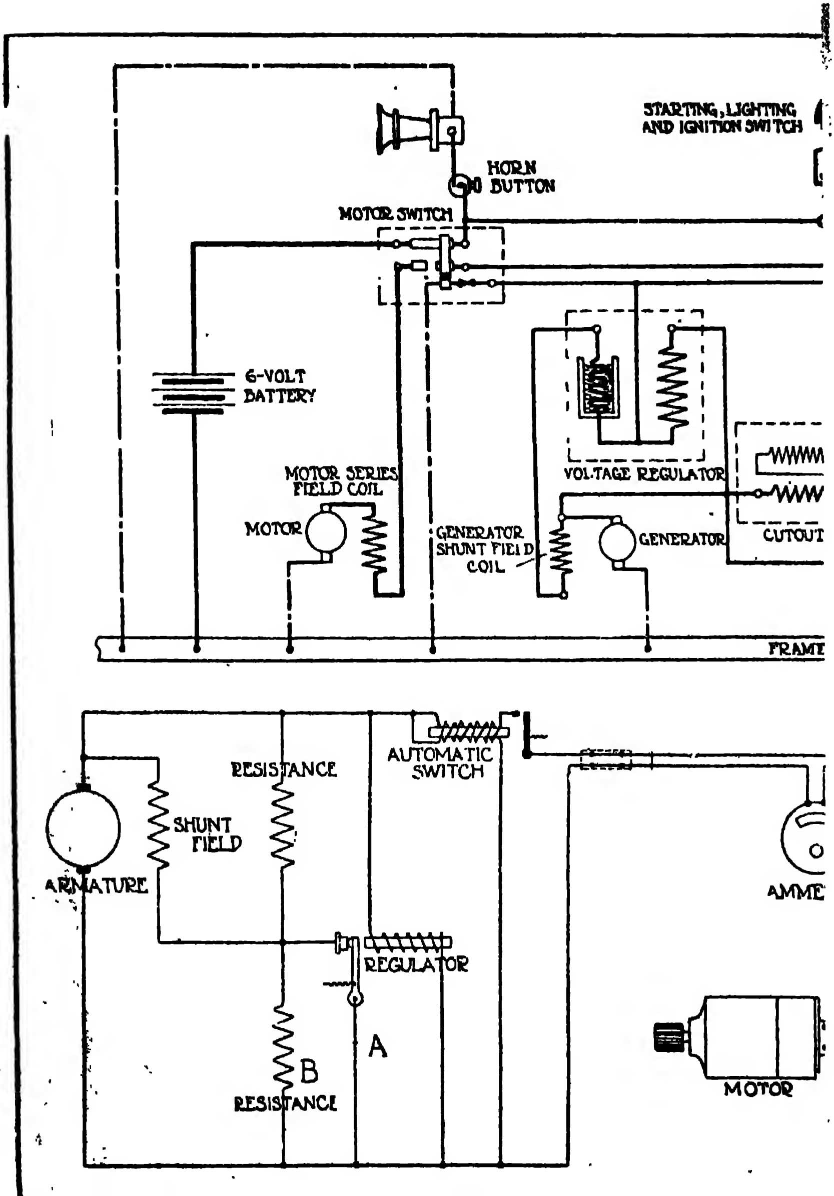


Fig. 302.—Wiring Diagram, Showing the Connections of the D

tem. The writer is indebted to the Horseless Age for the illustrations at Figs. 299 and 300.

Typical Wiring Diagrams, Delco System.—The various components of the Delco starting, lighting and ignition system have been outlined in the preceding chapter on ignition. A wiring diagram of the Delco-Olds system is shown at the top of Fig. 302 for those with a sufficient knowledge of electricity to be able to trace the various wires. All of the units are shown in diagram form, but the operation of the system may be easily understood if the description that has been previously given is studied in connection with the diagram. The ignition system will draw its current either from a five-cell dry battery or from the storage battery. The function of the ignition relay has been previously described. It will be observed that this system operates on the one wire method, all connections for return of current to the storage battery and the various units being made by the motor car frame. The broken lines indicate a ground connection, while the full lines designate wires. Considering the starting connections first, it will be apparent that one of the terminals of the storage battery is grounded to the frame, whereas the other is joined to one of the terminals of the starting switch. The other terminal of the starting switch is joined to the windings of the motor generator, which makes that device act as a motor to turn the engine crankshaft. The return from the motor windings to the storage battery is by means of a grounded return wire. With the switch in the position shown, the starting windings are not connected with the storage battery, but the generator windings are. One of the generator terminals is joined directly to the frame. The other passes through the cutout relay and through the voltage regulator, both of which have been previously described. Six of the terminals on the distributor head, which are for ignition, are joined to the spark plugs. The remaining terminal, which is in the center of the group, is joined to the secondary terminal of the ignition coil. The circuit through the secondary is completed through a grounding wire, which is in electrical contact with the grounded bodies of the spark plug. The insulated terminals of the spark plug are joined to the six terminals on the distributor head. The primary winding of the ignition coil

is joined to the circuit breaker through one terminal, this in turn passing through the dry battery to the ignition relay. The other terminal of the ignition coil is joined to the starting, lighting and ignition switch by a suitable conductor.

The arrangement of this switch is such that the current may be supplied directly to the head, side and tail lamps from the storage battery at all times that the switch circuit is closed. It is also possible to draw the ignition current either from the six-volt storage battery or from the battery of dry cells. The only time that the storage battery current flows through the starting motor windings is when the starting switch closes the circuit between the storage battery and the motor. At all other times the starting switch member is in such a position that the generator windings are in action and that the current from the armature is being passed into the storage battery.

Delco Motor Generator.—The motor generator which is located on the right side of the engine is the principal part of the Delco System. This consists essentially of a dynamo with two field windings, and two windings on the armature with two commutators and corresponding sets of brushes, in order that the machine may work both as a starting motor and as a generator for charging the battery and supplying the lights, horn and ignition. The ignition apparatus is incorporated in the forward end of the motor generator. This in no way affects the working of the generator, it being mounted in this manner simply as a convenient and accessible mounting.

The motor generator has three distinct functions to perform which are as follows: No. 1—Motoring the Generator. No. 2—Cranking the Engine. No. 3—Generating Electrical Energy.

Motoring the Generator.—Motoring the generator is accomplished when the ignition button on the switch is pulled out. This allows current to come from the storage battery through the ammeter on the combination switch, causing it to show a discharge. The first reading of the meter will be much more than the reading after the armature is turning freely. The current discharging through the ammeter during this operation is the current required to slowly revolve the armature and what is used for the ignition.

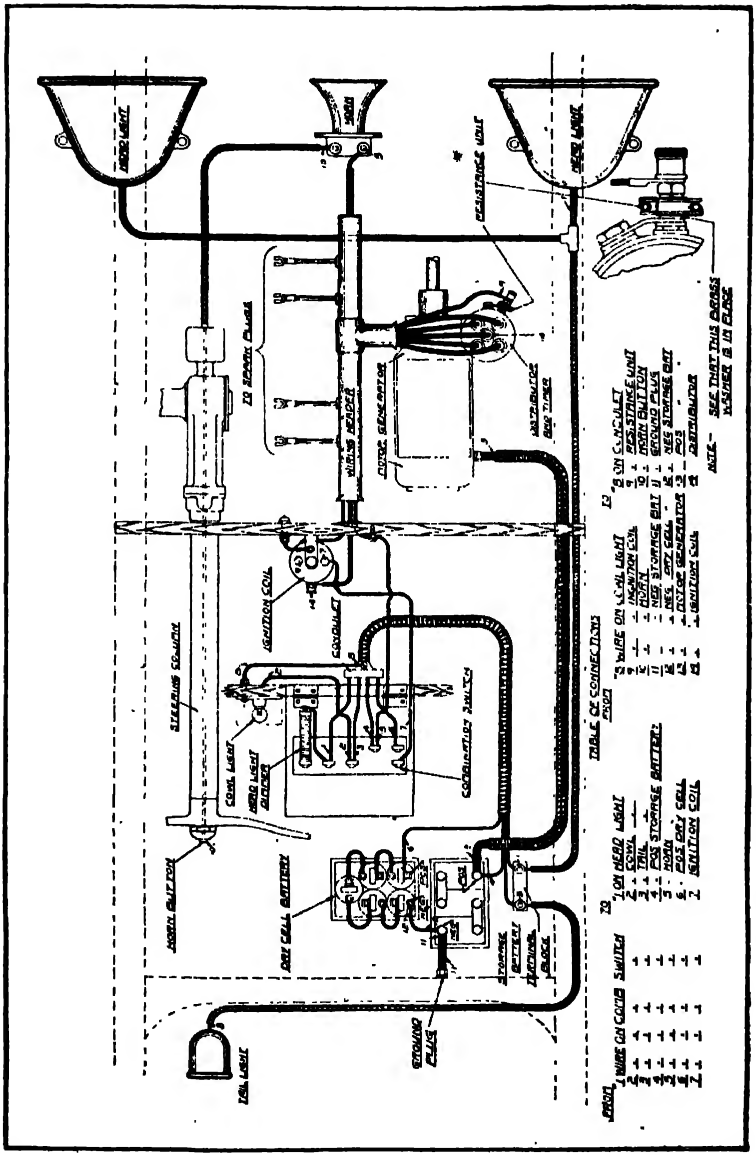


Fig. 303.—Wiring Diagram of Delco-Olds System in Non-Technical Form.

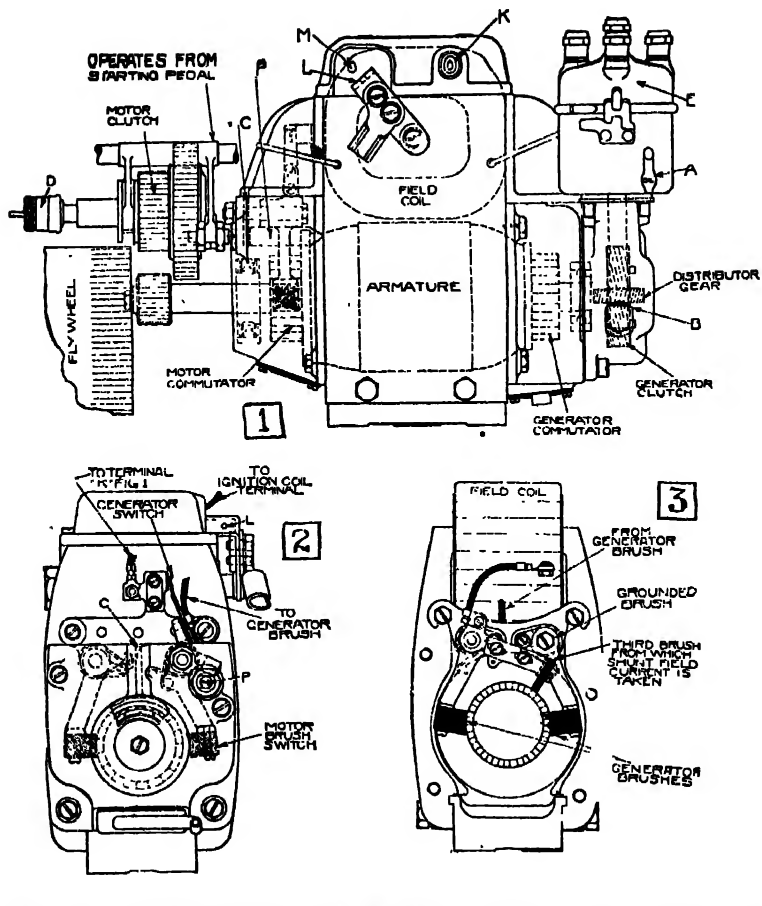


Fig. 303A.—Views Showing Arrangement of Parts of Delco Number 68 Motor-Generator. Note Double Commutator and Two Sets of Brushes.

The ignition current flows only when the contacts are closed, it being an intermittent current. The maximum ignition current is obtained when the circuit is first closed and the resistance unit on the rear end of the coil is cold. The current at this time is approximately 6 amperes, but soon decreases to approximately 3½ amperes. Then as the engine is running it further decreases until at 1,000 revolutions of the engine it is approximately 1 ampere.

This motoring of the generator is necessary in order that the starting gears may be brought into mesh, and should trouble be experienced in meshing these gears, do not try to force them, simply allow the starting pedal to come back, giving the gears time to change their relative position.

Generator Clutch.—A clicking sound will be heard during the motoring of the generator. This is caused by the overrunning of the clutch in the forward end of the generator which is shown in view 1, Fig. 303A.

The purpose of the generator clutch is to allow the armature to revolve at a higher speed than the pump shaft during the cranking operation and permitting the pump shaft to drive the armature when the engine is running on its own power. A spiral gear is cut on the outer face of this clutch for driving the distributor. This portion of the clutch is connected by an Oldham coupling to the pump shaft. Therefore, its relation to the pump shaft is always the same and does not throw the ignition out of time during the cranking operation. This clutch receives lubrication from the oil that is contained in the front end of the generator which is put in at B (view 1). This is to receive oil each week sufficient to bring the oil up to the level of the oiler. The arrangement of clutch parts is shown at Fig. 303B.

Cranking Operation.—The cranking operation takes place when the starting pedal is fully depressed. The starting pedal brings the motor clutch gears (view 1) into mesh and withdraws the pin P, (views 1 and 2) allowing the motor brush switch to make contact on the motor commutator. At the same time the generator switch breaks contact. This cuts out the generator element during the cranking operation. As soon as the motor brush makes contact on the commutator a heavy current from the storage battery flows through the series field winding and the motor winding on the armature. This rotates the armature and performs the cranking operation. The cranking circuit is shown in the heavy lines on the circuit diagram (Fig. 303J). This cranking operation requires a heavy current from the storage battery, and if the lights are on during the cranking operation, the heavy discharge from the battery causes the voltage of the battery to decrease enough to cause

the lights to grow dim. This is noticed especially when the battery is nearly discharged; also will be more apparent with a stiff motor or with a loose or poor connection in the battery circuit or a nearly discharged battery. It is on account of this heavy discharge current that the cranking should not be continued any longer than is necessary, although a fully charged battery will crank the engine for several minutes.

During the cranking operation the ammeter will show a discharge. This is the current that is used both in the shunt field

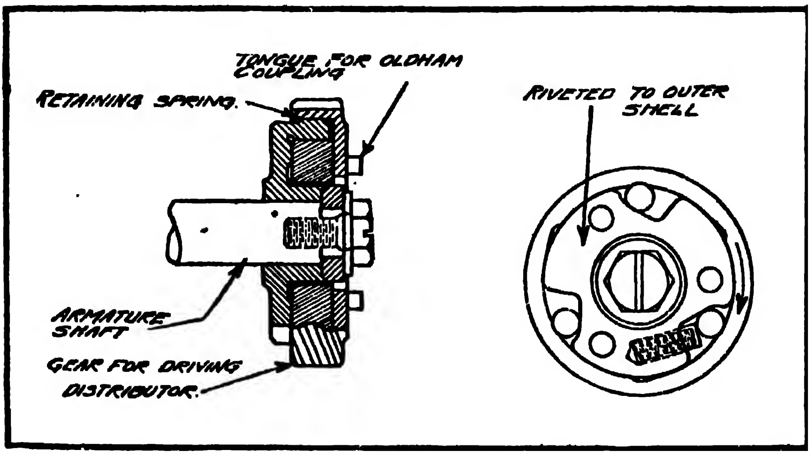


Fig. 303B.—Generator Driving Clutch Only Transmits Power When Engine Speed is Greater Than Armature Speed.

winding and the ignition current; the ignition current being an intermittent current of comparatively low frequency will cause the ammeter to vibrate during the cranking operation. If the lights are on the meter will show a heavier discharge. The main cranking current is not conducted through the ammeter, as this is a very heavy current and it would be impossible to conduct this heavy current through the ammeter and still have an ammeter that is sensitive enough to indicate accurately the charging current and the current for lights and ignition. As soon as the engine fires the starting pedal should be released immediately, as the overrunning motor

clutch is operating from the time the engine fires until the starting gears are out of mesh.. Since they operate at a very high speed, if they are held in mesh for any length of time, there is enough friction in this clutch to cause it to heat and burn out the lubricant. There is no necessity for holding the gears in mesh.

Motor Clutch.—The motor clutch operates between the flywheel and the armature pinion for the purpose of getting a suitable gear reduction between the motor generator and the flywheel. It also prevents the armature from being driven at an excessively high speed during the short time the gears are meshed after the engine is running on its own power. This cup is lubricated by the grease cup A, shown in view 1, Fig. 303A. This forces grease through the hollow shaft to the inside of the clutch. This cup should be given a turn or two every week.

Generating Electrical Energy.—When the cranking operation is finished the motor brush switch is raised off the commutator by the pin P when the starting pedal is released. This throws the starting motor out of action. As the motor brush is raised off the commutator the generator switch makes contact and completes the charging circuit. The armature is then driven by the extension of the pump shaft and the charging begins. At speeds above approximately 7 miles per hour the generator voltage is higher than the voltage of the storage battery which causes current to flow from the generator winding through the armature in the charge direction to the storage battery. As the speed increases up to approximately 20 miles per hour this charging current increases, but at the higher speeds the charging current decreases. The curve, Fig. 303C, shows approximately the charging current that should be received for different speeds of the car. There will be slight variations from this due to temperature changes and conditions of the battery which will amount to as much as from 2 to 3 amperes. The regulation of the generator is explained in section 2.

Lubrication.—There are five places to lubricate this Delco System. No. 1—The grease cup for lubricating the motor clutch (D, view 1, Fig. 303A). No. 2—Oiler for lubricating the generator clutch and forward armature bearing (B). No. 3—The oil hole (C) for lubricating the bearings on the rear of the armature shaft

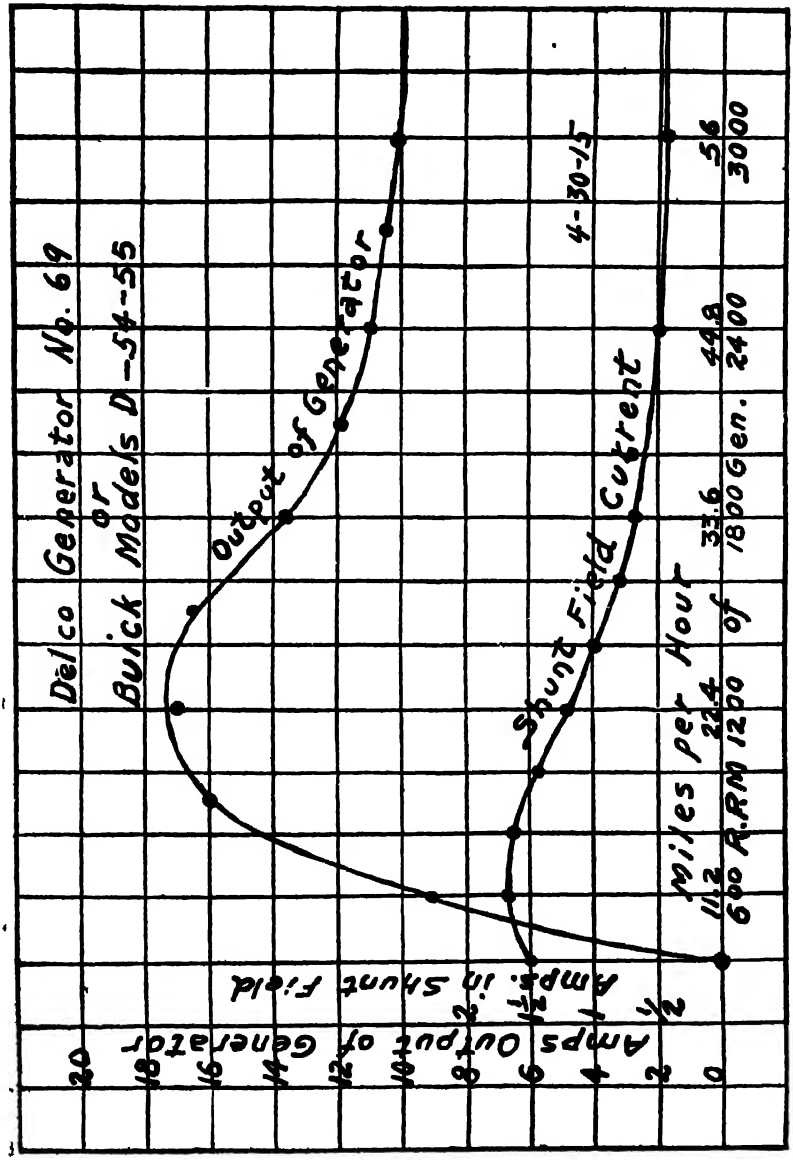


Fig. 303C.—Curves Showing Output of Delco Generator Number 68 at Various Engine Speeds.

This is exposed when the rear end cover is removed. This should receive oil once a week. No. 4—The oil hole in the distributor, at A, for lubricating the top bearing of the distributor shaft. This should receive oil once a week. No. 5—This is the inside of the distributor head. This should be lubricated with a small amount of vaseline, carefully applied two or three times during the first 2,000 miles running of the car, after which it will require no attention. This is to secure a burnished track for the rotor brush on the distributor head. This grease should be sparingly applied and the head wiped clean from dust and dirt.

Method of Current Output Regulation.—The voltage regulator which has been previously described and which was used on the 1914 and 1915 Delco Systems has been replaced by a system of "third brush excitation" in the 1916 systems. This has been very concisely described by the Delco engineers, and in order to make for accurate presentation of fact, the following descriptive matter is given in the same way as it appears in the Delco instruction books.

There is really only one point in regard to the generating of electrical energy which is difficult to understand, and the best of scientists are at as much of a loss on this point as the average electrician. This one point can be expressed in the one sentence which is as follows: "Whenever the strength of the magnetic field or the amount of magnetism within a coil is changed an electro-motive force is induced or generated." This is variously expressed, but can be resolved into the same sentence as originally given. One of the most common expressions is, "Whenever an electrical conductor cuts the magnetic field or cuts magnetic lines of force an electro-motive force is induced." In order to measure this electro-motive force, it is necessary to make connection from each end of the conductor to a suitable meter, by doing this a coil would be formed. Therefore, this expression means nothing different from the original expression. On account of being more readily understood, this expression will be referred to in connection with the explanation of the action of the generator.

The amount of the voltage that is induced (or generated) in any conductor or coil varies directly with the rate of the cutting of the magnetic lines; *e.g.*, if we have a generator in which the magnetic

field remains constant and the generator produces 7 volts at 400 R. P. M., the voltage at 800 R. P. M. would be 14 volts, and it is on *account of the variable speed of generators for automobile purposes that they must be equipped with some means of regulation for* holding the voltage very nearly constant. The regulation of this generator is by what is known as third brush excitation, the theory of which is as follows:

The motor generator consists essentially of an iron frame and a field coil with two windings for magnetizing this frame. The armature, which is the revolving element, has wound in slots on its iron core a motor winding and a generator winding connected to corresponding commutators. Each commutator has a corresponding set of brushes which are for the purpose of collecting current from, or delivering current to the armature windings while the armature is revolving.

When cranking, current from the storage battery flows through the motor winding magnetizing the armature core. This acting upon the magnetism of the frame causes the turning effort. When generating the voltage is induced in the generator winding and when the circuit is completed to the storage battery this causes the charging current to flow into the battery. The brushes are located on the commutator in such a position that they collect the current while it is being generated in one direction. (The current flows one direction in a given coil while it is passing under one pole piece and in the other direction when passing under the opposite pole piece.) When the ignition button on the combination switch is first pulled out the current flows from the storage battery through the generator armature winding, also through the shunt field winding. This causes the motoring of the generator. After the engine is started and is running on its own power this current still has a tendency to flow in this direction, but is opposed by the voltage generated. At very low speeds a slight discharge is obtained. At approximately 7 miles per hour the generated voltage exceeds that of the battery and charging commences. As the speed increases above this point the charging rate increases as shown by the curve (Fig. 303C). The regulation of this generator is effected by what is known as third brush excitation.

Since the magnetic field of the generator is produced by the current in the shunt field winding it is evident that should the *shunt field current decrease as the speed of the engine increases the regulation would be affected. In order to fully understand this* explanation it must be borne in mind that a current of electricity always has a magnetic effect whether this is desirable or not. Referring to Fig. 303D, the theory of this regulation is as follows: *The full voltage of the generator is obtained from the large brushes marked "C" and "D."* When the magnetic field from the pole pieces N and S is not disturbed by any other influence each coil is generating uniformly as it passes under the pole pieces. The voltage from one commutator bar to the next one is practically uniform around the commutator. Therefore, the voltage from brush C to brush E is about 5 volts when the total voltage from brush C to brush D is 6½ volts and 5 volts is applied to the shunt field winding. This 5 volts is sufficient to cause approximately 1¼ amperes to flow in the shunt field winding.

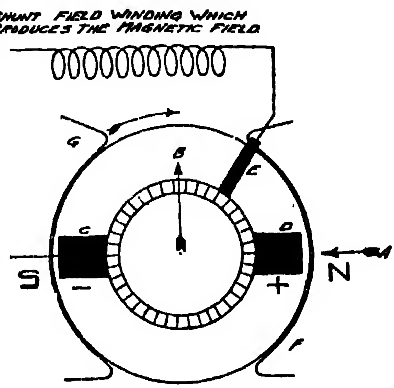


Fig. 303D.—Diagram Illustrating Function of Third Brush In Regulating Delco Generator Output.

As the speed of the generator is increased the voltage increases, causing the current to be charged to the storage battery. This charging current flows through the armature winding, producing a magnetic effect in the direction of the arrow B. This magnetic effect acts upon the main magnetic field which is in the direction of the arrow A with the result that the magnetic field is twisted out of its original position in very much the same manner as two streams of water coming together are each deflected from their original directions. This deflection causes the magnetic field to be

strong at the pole tips, marked G and F, and weak at the opposite pole tips with the result that the coils generate a very low voltage while passing from the brush C to the brush E (the coils at this time are under the pole tips having a weak field) and generates a greater part of their voltage while passing from the brush E to D. The amount of this variation depends upon the speed that the generator is driven; with the result that the shunt field current decreases as the speed increases as shown in the curve.

By this form of regulation it is possible to get a high charging rate between the speeds of 12 and 25 miles per hour, and it is with drivers whose average driving speed comes between these limits that more trouble is experienced in keeping the battery charged. At the higher speeds the charging current is decreased. The driver who drives his car at the higher speeds requires less current, as experience has taught that this type of driver makes fewer stops in proportion to the amount the car is driven than the slower driver. The output of these generators can be increased or decreased by changing the position of the regulating brush. Each time the position of the brush is changed it is necessary to sandpaper the brush so that it fits the commutator. Otherwise the charging rate will be very low due to the poor contact of the brush. This should not be attempted by any one except competent mechanics, and this charging current should be carefully checked and in no case should the maximum current on this generator exceed 22 amperes. Also careful watch should be kept on any machine on which the charging rate has been increased to see that the commutator is not being overloaded. Considerable variation in the output of different generators will be obtained from the curve shown, as the output of the generator is affected by temperature and battery conditions.

Condenser.—The condenser consists of two long strips of folded tinfoil insulated from each other by paraffined or oiled paper, and connected as shown in Fig. 303E. The condenser has the property of being able to hold a certain quantity of electrical energy, and like the storage battery, will discharge this energy if there is any circuit between its terminal. As the distributor contacts open the magnetism commences to die out of the iron core, this induces a voltage in both the primary and secondary windings of the coil.

This induced voltage in the primary winding amounts to from 100 to 125 volts. This charges the condenser which immediately discharges itself through the primary winding of the coil in the reverse direction from which the ignition current originally flows. This discharge of the condenser causes the iron core of the coil to be

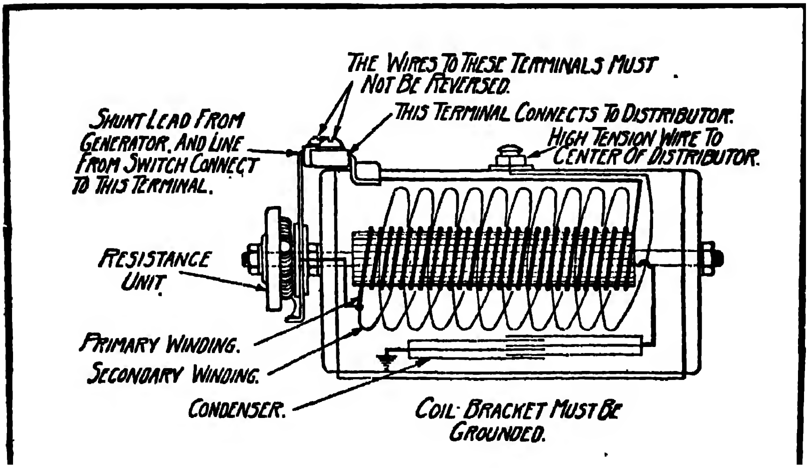


Fig. 303E.—Diagram Showing Internal Wiring of Delco Ignition Coil.

quickly demagnetized and remagnetized in the reverse direction, with the result that the change of magnetism within the secondary winding is very rapid, thus producing a high voltage in the secondary winding which is necessary for ignition purposes. In addition to rapidly demagnetizing the coil the condenser prevents sparking at the breaker contacts—thus it is evident that the action of the condenser can very seriously affect the amount of the spark from the secondary winding and the amount of sparking obtained at the timer contacts.

Ignition Coil.—This is sometimes mounted on top of the motor generator and is what is generally known as the ignition transformer coil. In addition to being a plain transformer coil it has incorporated in it a condenser (which is necessary for all high tension ignition systems) and has included on the rear end an

ignition resistance unit. The coil proper consists of a round core of a number of small iron wires. Wound around this and insulated from it is the primary winding. The circuit and arrangement of the different parts are shown in Fig. 303E. The primary current is supplied through the combination switch and resistance on the coil, through the primary winding, to the distributor contacts. This is very plainly shown on the circuit diagram, Fig. 303J. It is the interrupting of this primary current by the timer contacts together with the action of the condenser which causes a rapid demagnetization of the iron core of the coil that induces the high tension current in the secondary winding. This secondary winding consists of several thousand turns of very fine copper wire, the different layers of which are well insulated from each other and from the primary winding, one end of which terminates at the high tension terminal about midway on top of the coil. It is from this terminal that the high tension current is conducted to the distributor where it is distributed to the proper cylinders by the rotor shown in Fig. 303H.

Ignition Resistance Unit.—The ignition resistance unit which is shown in Fig. 303E is for the purpose of obtaining a more nearly uniform current through the primary winding of the ignition coil at the time the distributor contacts open. It consists of a number of turns of iron wire, the resistance of which is considerably more than the resistance of the primary winding of the ignition coil. If the ignition resistance unit was not in the circuit and the coil was so constructed as to give the proper spark at high speeds, the primary current at low speeds would be several times its normal value with serious results to the timer contacts. This is evident from the fact that the primary current is limited by the resistance of the coil and resistance unit by the impedence of the coil. (Impedence is the choking effect which opposes any alternating or pulsating current magnetizing the iron core.) The impedence increases as the speed of the pulsations increase. At low speeds the resistance of the unit increases, due to the slight increases of current heating the resistance wire.

The Circuit Breaker.—The circuit breaker is mounted on the combination switch as shown in Fig. 303F. This is a protective device which takes the place of a fuse block and fuses. It prevents

the discharging of the battery or damage to the switch or wiring to the lamps, in the event of any of the wires leading to these becoming grounded. As long as the lamps are using the normal amount of current the circuit breaker is not affected. But in the event of any of the wires becoming grounded an abnormally heavy

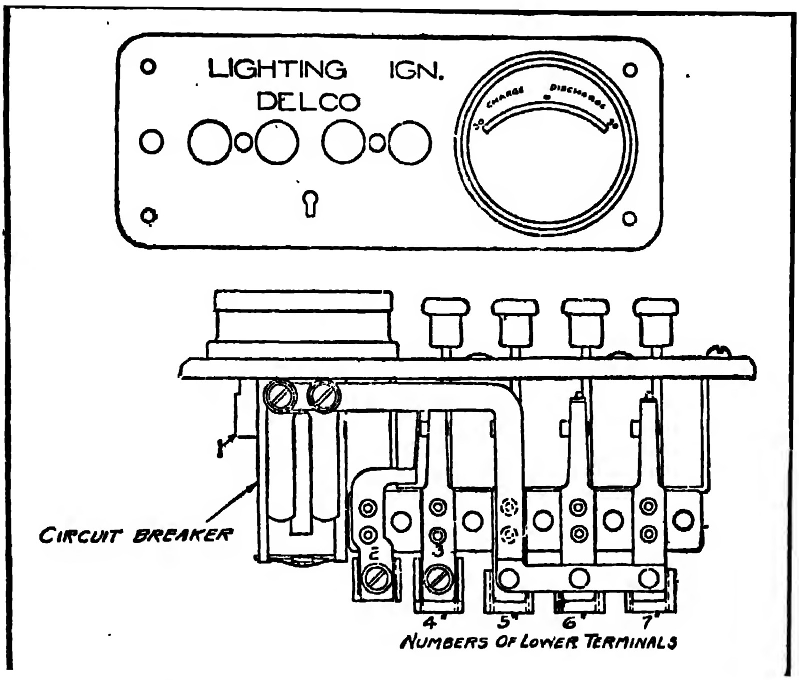


Fig. 303F.—Views of Delco Combination Switch With Indicating Amperemeter Combined.

current is conducted through the circuit breaker, thus producing a strong magnetism which attracts the pole piece and opens the contacts. This cuts off the flow of current which allows the contacts to close again and the operation is repeated, causing the circuit breaker to pass an intermittent current and give forth a vibrating sound. It requires 25 amperes to start the circuit breaker vibrating, but once vibrating a current of three to five amperes will cause

it to continue to operate. In case the circuit breaker vibrates repeatedly, do not attempt to increase the tension of the spring, as the vibration is an indication of a ground in the system. Remove the ground and the vibration will stop.

The Ammeter.—The ammeter on the right side of the combination switch is to indicate the current that is going to or coming

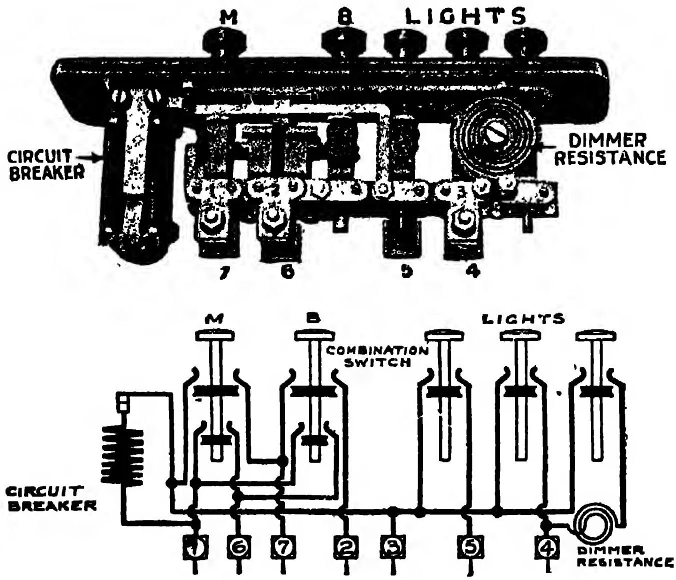


Fig. 303G.—View of Delco Combination Switch and Circuit Diagram for Same.

from the storage battery, with the exception of the cranking current. When the engine is not running and current is being used for lights, the ammeter shows the amount of current that is being used and the ammeter hand points to the discharge side, as the current is being discharged from the battery. When the engine is running above generating speeds and no current is being used for lights or horn, the ammeter will show charge. This is the amount of current that is being charged into the battery. If current is being used for

lights, ignition and horn in excess of the amount that is being generated, the ammeter will show a discharge as the excess current must be discharged from the battery, but at all ordinary speeds the ammeter will read charge. The charging rate for different car speeds when no current is being used for lights or horn, is given in the curve, Fig. 303C.

Construction of Delco Ignition Distributor.—It is well understood that a rich mixture burns quicker than a lean one. For this reason the engine will stand more advance with a half open throttle than with a wide open throttle, and in order to secure the proper timing of the ignition due to these variations and to retard the spark for starting, idling and carburetor adjusting, the Delco distributor also has a manual control. The automatic feature of this distributor is shown in Fig. 303H. With the spark lever set at the running position on the steering wheel (which is nearly all the way down on the quadrant), the automatic feature gives the proper spark for all speeds excepting a wide open throttle at low speeds, at which time the spark lever should be slightly retarded. When the ignition is too far ad-

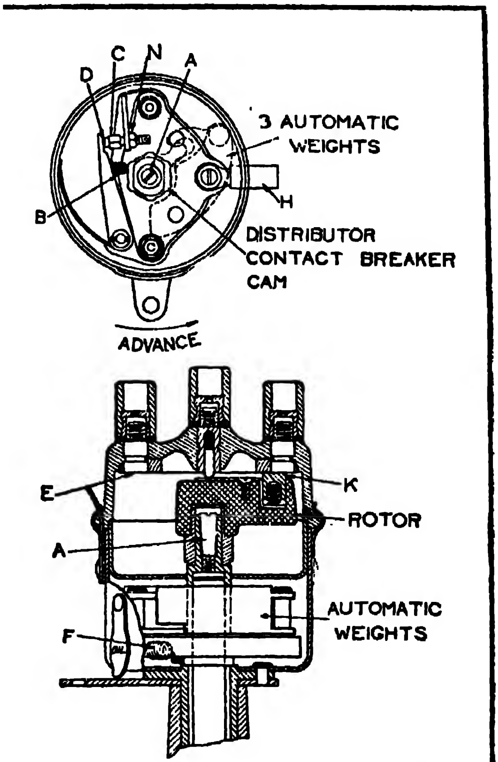


Fig. 303H.—Showing Construction of 1916 Delco Distributor for Six Cylinder Ignition. Note Six Lobe Cam.

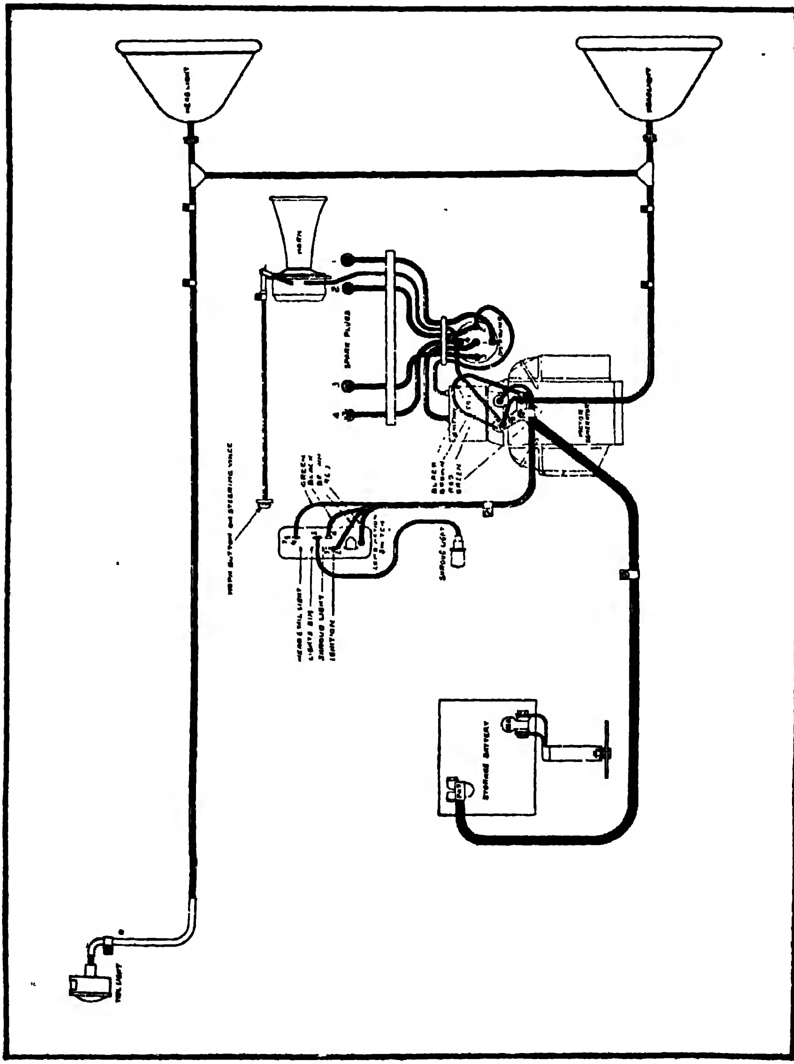


Fig. 303I.—Arrangement of Wiring of Delco-Oakland Starting, Lighting and Ignition System.

vanced it causes loss of power and a knocking sound within the engine. With too late a spark there is a loss of power (which is usually not noticed excepting by an experienced driver or one very familiar with the car), and heating of the engine and excessive consumption of fuel is the result. The timer contacts shown at D and C (Fig. 303H) are two of the most important points of an automobile. Very little attention will keep these in perfect condition. These are tungsten metal, which is extremely hard and requires a very high temperature to melt. Under normal conditions they wear or burn very slightly and will very seldom require attention; but in the event of abnormal voltage, such as would be obtained by running with the battery removed, or with the ignition resistance unit shorted out, or with a defective condenser, these contacts burn very rapidly and in a short time will cause serious ignition trouble. The car should not be operated with the battery removed.

It is a very easy matter to check the resistance unit by observing its heating when the ignition button is out and the contacts in the distributor are closed. If it is shorted out it will not heat up, and will cause missing at low speeds. A defective condenser such as will cause contact trouble will cause serious missing of the ignition. Therefore, any one of these troubles are comparatively easy to locate and should be immediately remedied. These contacts should be so adjusted that when the fiber block B is on top of one of the lobes of the cam the contacts are opened the thickness of the gauge on the distributor wrench. Adjust contacts by turning contact screw C and lock with nut N. The contacts should be dressed with fine emery cloth so that they meet squarely across the entire face. The rotor distributes the high tension current from the center of the distributor to the proper cylinder. Care must be taken to see that the distributor head is properly located, otherwise the rotor brush will not be in contact with the terminal at the time the spark occurs.

Combination Switch.—The combination switch is located on the cowl board and makes the necessary connections for ignition and lights. The "M" button controls the magneto type ignition and the "B" button, the dry battery ignition. In addition to this both

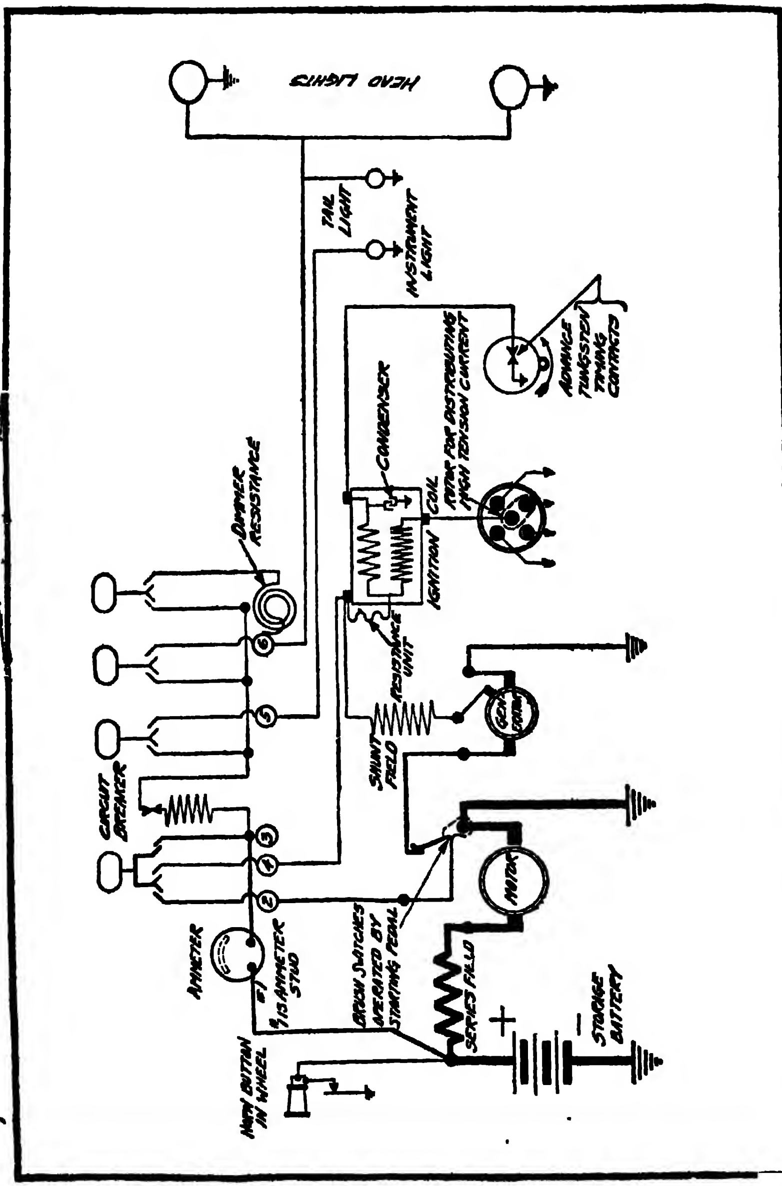


Fig. 303J.—Circuit Diagram of Delco-Oakland Starting, Lighting and Ignition System.

the "M" and "B" buttons control the circuit between the generator and storage battery. When the circuit between the generator and the storage battery is closed by either the "M" or "B" button on the combination switch, the direction of flow of the current is from the battery to the generator when the engine is not running, as well as when it is running below 300 R. P. M. But the amount of current that flows from the battery at the lowest possible engine speeds is so small that it is negligible. That used on Buick 1915 cars is shown at Fig. 303G, the type supplied on 1916 cars is out lined at Fig. 303F.

To Time the Ignition.—1. Fully retard the spark lever. 2. Turn the engine to mark on flywheel about one inch past dead center to the "7 degree" line, with No. 1 cylinder on the firing stroke. 3. Loosen screw in center of timing mechanism and locate the proper lobe of the cam by turning until the button on the rotor comes under the high tension terminal for No. 1 cylinder. 4. Set this lobe of the cam so that when the back lash in the distributor gears is rocked forward the timing contacts will be open, and when the back lash is rocked backward the contacts WILL JUST CLOSE. Tighten screw and replace rotor and distributor head.

Hints for Locating Trouble.—1. If starter, lights and horn all fail, the trouble is in the storage battery or its connections, such as a loose or corroded connection or a broken battery jar. 2. If the lights, horn and ignition are all O. K., but the starter fails to crank, the trouble is in the motor generator, such as dirt or grease on the motor commutator, or the motor brush not dropping on the commutator. 3. If the starter fails to crank or cranks very slowly, and the lights go out or get very dim while cranking, it indicates a loose or corroded connection on the storage battery, or a nearly depleted storage battery. 4. If the motor fires properly on the "M" button, but not on the "B" button, the trouble must be in the wiring between the dry cells or the wires leading from the dry cells to the combination switch, or depleted dry cells. If the ignition works O. K. on the "B" button and not on the "M" button, the trouble must be in the leads running from the storage battery to the motor generator, or the lead running from the rear terminal on the generator to the combination switch, or in the storage battery

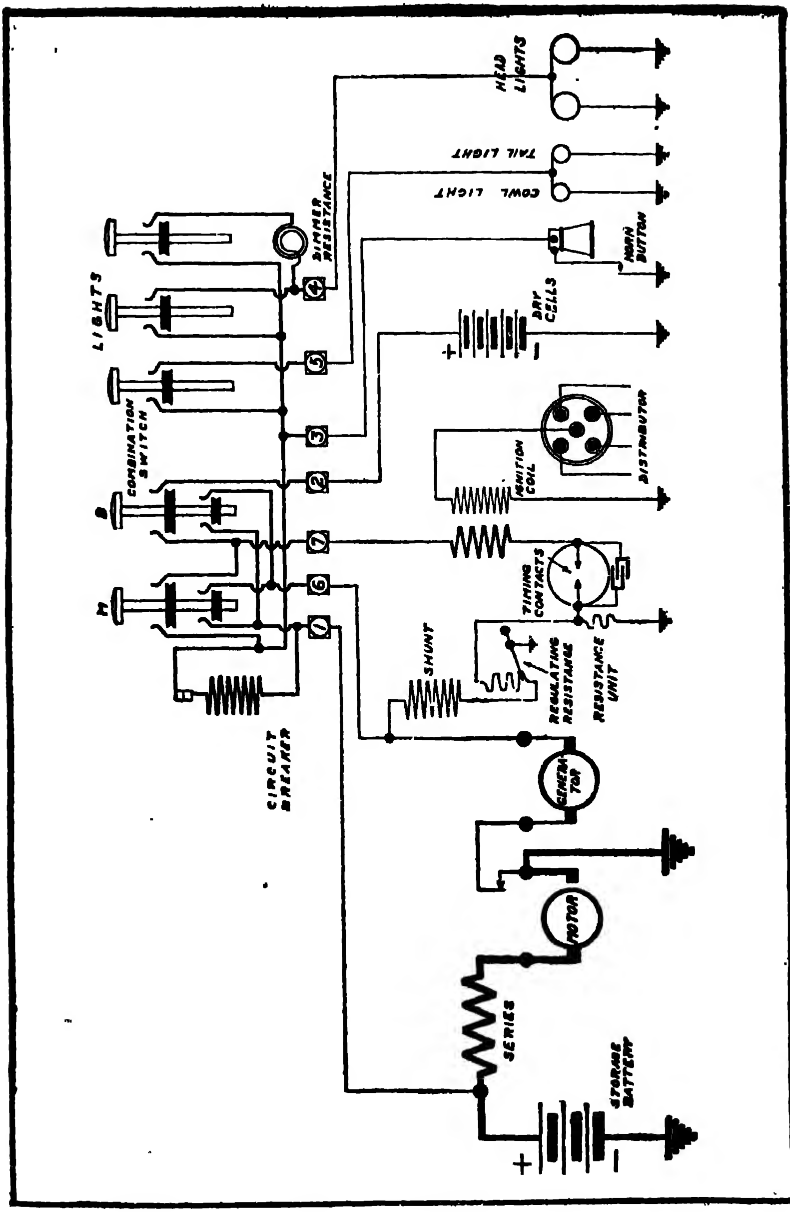


Fig. 303K.—Circuit Diagram of 1915 Delco-Buick Starting, Lighting and Ignition System.

itself, or its connection to the frame of the car. 5. If both systems of ignition fail, and the supply of current from both the storage battery and dry cells is O. K., the trouble must be in the coil, resistance unit, timer contacts or condenser. This is apparent from the fact that these work in the same capacity for each system of ignition.

Never run the car with the storage battery disconnected, or while it is off the car. Very serious damage to the motor-generator may result from such action.

Never remove any electrical apparatus from the car or make any adjustments without first disconnecting the storage battery. This can be done most conveniently by removing the ground connection. Remember, a loose, corroded or dirty connection on the battery can put both starting and lighting systems out of commission.

Bijur-Packard System.—The self-starting and lighting system, Fig. 302, used on the Packard, is manufactured by the Bijur Motor Lighting Co. In this system the starting motor and generator are separate units. The starting circuit is simple, consisting of a motor connected directly to the battery and operated by closing a starting switch.

In the generator circuit the principal parts are: The generator; an automatic switch for breaking the circuit when the speed of the generator becomes so low that the battery current would discharge through it, and a voltage regulator of the vibrator type. A study of the wiring diagram shows that the automatic switch has two coils, a voltage coil of high resistance connected across the wires leading to the battery and a current coil in series with the generator and battery. The action of this coil is such that as the armature speed increases and the voltage becomes greater, the magnetism generated in this coil attracts a small steel arm, thus completing circuit between the battery and the generator. Current then flows to the battery and lights.

On the other hand, as the speed of the generator decreases, its voltage becomes less and finally a point is reached where the current begins to flow back into the generator. This reversal of flow produces a magnetic field in the series coil of the cutout which

opposes the field produced by the voltage coil, until finally the attraction of the latter for the steel arm that completes the circuit is entirely overcome and then the arm, impelled by a spring, breaks contact.

The voltage regulator operates on the vibrator principle, and is designed so that when the voltage becomes higher than the predetermined amount the vibrator throws a resistance into circuit that reduces the amount of current flowing through the field. This diminishes the voltage. When the voltage becomes too low, the vibrator flies back again and allows full current to pass through the field once more. The movement of this vibrator is extremely rapid, making about 150 oscillations per second, so that in actual practice, no change in voltage, in one direction or the other, is noticeable.

Now looking at the diagram, it is seen that this regulator consists of a vibrating arm which is actuated by an electro-magnet connected across the mains running from the generator. When this arm is not attracted by the magnet, full field current is allowed to flow through wire A from one generator lead up through the shunt field to the other lead of the generator, thus full field strength is obtained and a rising voltage is generated, which finally causes the magnet coil to pull this arm out of contact, thus breaking the circuit. When this occurs, the current must flow to the field through the resistance B, and this resistance reduces the flow of the current and weakens the field so that the generated voltage drops. This reduction in voltage causes a smaller current to flow through the magnet winding and then the attraction of the magnet weakens, allowing the arm to fly back, thus enabling full current to flow through the field again. This cycle is repeated 150 times a second. Special provision has been made so that the contact points on the regulator will not burn away.

There is nothing unusual in the wiring, which may be easily followed from the diagram.

Hartford Starting System.—The wiring diagram at Fig. 304 shows clearly the method of connecting the various appliances forming part of the Hartford starting and lighting system. This is a 12 volt, two wire starting system, with a connection so the lamps receive their current from the battery on the three wire sys-

tem. The two terminals of the generator are connected to the storage battery in the usual way, one directly to a terminal, the other through the automatic cutout. When the knife-switch is closed, the battery current flows through the motor windings and turns the engine crankshaft. The connections are so clearly shown that further description is unnecessary. The speed of the generator armature is governed by the centrifugal governor, which is designed to keep it at 1200 revolutions per minute. The lighting switch is of the selective barrel type, having three positions of the handle, one of which will give the head and rear lamps, the intermediate position lighting the side and rear, while the last position sends the current through all the lamps. This switch is not shown in the diagram.

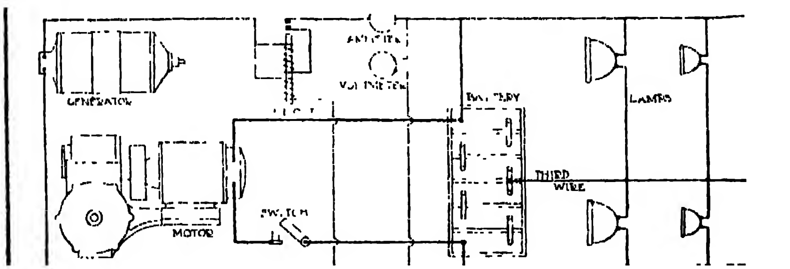


Fig. 304.—Wiring Diagram of Hartford 12 Volt Starting System, Having Three-Wire Method of Supplying Current to 6 Volt Lamps.

The Auto-Lite System.—The 1915 Overland cars use the Auto-Lite system, which is shown at Fig. 305, A. This is a six volt, three unit system, operating on the one wire principle. The ignition function is performed by an entirely distinct appliance from the starting and lighting systems, namely, a high tension magneto. Five wires run from this magneto, four of these running the spark plugs, one for interrupting the ignition through a fuse box to the controlling switch. The generator is driven from the motor crankshaft by a silent chain. The starting motor, which has the switch mounted integrally, turns the engine crankshaft through a gear cut on the flywheel rim. One of the wires of the generator is grounded,

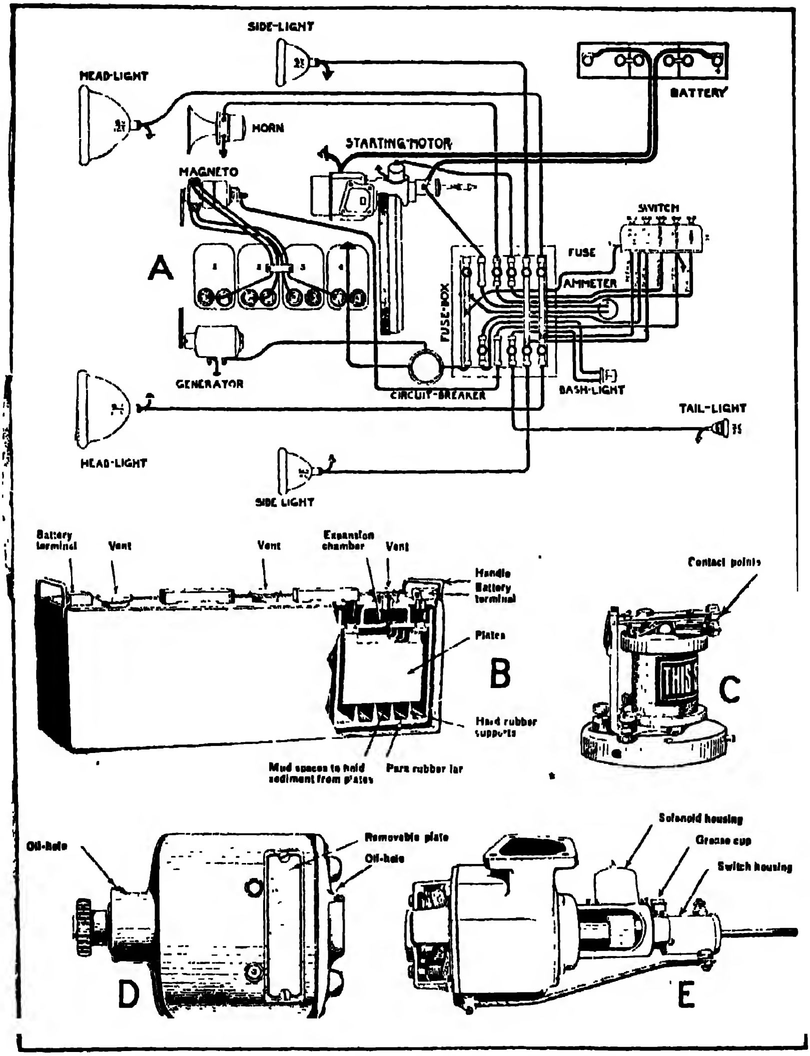


Fig. 305.—Complete Wiring Diagram of Starting and Lighting System Used on 1915 Overland Automobiles at A, Part Sectional View of Storage Battery at B, Design of Circuit Breaker Shown at C, External View of Generator at D, and Starting Motor Construction at E.

the remaining wire leading from that device runs through the circuit breaker and from that member through the fuse box and switch to the storage battery. Two wires run from the six volt battery, one of these terminating on a switch terminal of the starting motor while the other attaches to one of the motor terminals. The remaining motor terminal is grounded. The various appliances comprising this system are all clearly shown, and the wiring may be easily traced from the various units through the fuse box and switch by careful study of the diagram. In order to simplify wiring, the wires going to the switch are all colored differently. This insures that they will be replaced on the proper terminals if removed.

The storage battery used with this system is shown at Fig. 305, B. It is a special form, in which the three cells are placed end to end instead of side by side, making a long, narrow battery instead of the usual construction, which is approximately square. The construction of the circuit breaker is shown at C, the contact points, which are the only parts needing attention, being clearly outlined. The generator, which is a very simple device, is shown at B, the points requiring lubrication, and the removable plates for inspection of the brushes are clearly depicted. The starting motor is shown at E, the pinion which engages the gear on the flywheel is shown mounted on the armature shaft, and the cover, which normally covers the brush end of the motor, is removed in order to show the method of reaching the motor brushes when these members need attention.

Gray & Davis System.—The starting and lighting equipment used on the Model 79, 1914 Overland, is the Gray & Davis system, shown at Fig. 306, and comprises three principal units:

a—The generator which produces the current and delivers it to the lamps and storage battery.

b—The storage battery which accumulates the current thus generated and delivers it to the lighting system or the starting motor, as occasion demands.

c—The starting motor, which receives current from the storage battery and revolves the engine whenever it is to be set in motion.

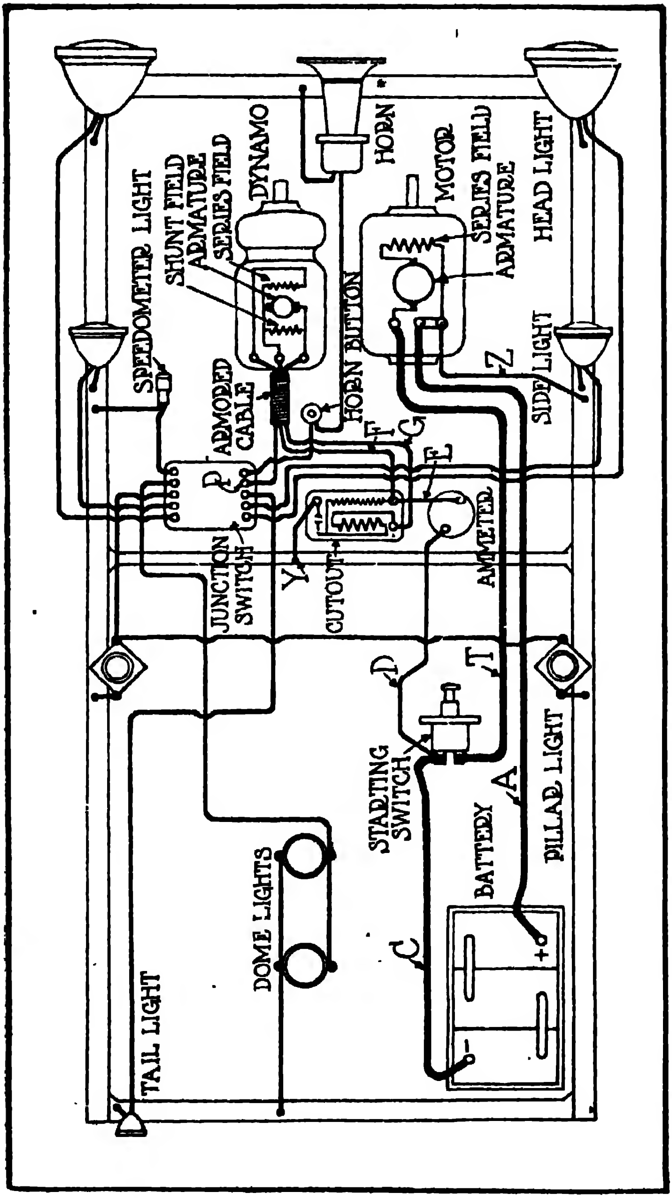


Fig. 306.—Wiring Diagram of Overland Gray & Davis Two Unit Starting and Lighting System.

Besides these three principal units the system includes the following auxiliary apparatus:

d—An automatic cutout, whose function is to disconnect the generator from the storage battery when the engine is stopped or running below the speed at which the generator's voltage is high enough to charge the battery. The cutout is located on the engine side of the dash.

e—The starting switch, which is a pedal-button located in the floor board of the car convenient to the foot of the operator.

f—The ammeter, whose purpose is to show whether the system is working properly or not. When the dynamo is running and sending current to the storage battery the ammeter hand will point to the right of zero or at "charge." When the lights are burning or the starter motor is running, this hand will point to the left of zero or at "discharge," thus indicating the rate at which current is going out of the storage battery.

The speed of the generator is controlled by an automatic clutch that is so designed that, no matter how fast the engine runs, the generator will not be driven faster than a certain predetermined speed which corresponds to that at which the engine runs when driving the car at 12 miles per hour on high gear, but, of course, if the engine drops below this speed the generator will also. This is done by means of a centrifugal governor which regulates the slippage of the clutch so that the generator cannot be driven faster than the predetermined speed, the greater the speed of the engine the more the clutch slips.

The current load is automatically taken care of by a compound winding on the generator. The starting motor is a series wound machine, that is, the entire armature current passes through the field. The motor is provided with an over-running clutch, which allows it to drive the engine but automatically disengages when the engine starts so that the engine will not drive the motor. If such a device were not fitted the generator might be injured by the motor driving it at too high a speed.

As already explained, the function of the automatic cutout is to disconnect the generator from the battery when the engine is stopped or turning so slowly that its voltage is below that of the

battery. If this cutout were not provided the storage battery would discharge back into the generator.

The cutout consists of an electro-magnet with two windings. One is a shunt winding of many turns of fine wire and the other a series winding of a few turns of heavy wire, both windings being over a soft iron core. The shunt winding is permanently connected across the positive and negative terminals of the generator, so that when the generator comes up to charging speed, this winding energizes the magnet core and the magnet core attracts a steel arm that closes the circuit between the generator and the battery.

So long as the cutout points are closed the current must pass through the series winding of the cutout. This current adds its magnetizing influence to that of the shunt winding and holds the points together. The cutout is designed so that it closes at a car-speed of 12 miles per hour and opens at 10.

If, now, the speed of the generator drops below charging speed, the current begins to flow through the cutout series winding in the reverse direction. This weakens the pull and allows the points to fly apart, through the agency of a spring.

Now that a general idea of the different parts of the Gray & Davis system has been obtained, the path of the current in the different wires will be explained. The illustration shows this system with a very complete equipment. Besides the usual head, side and tail lights, there are pillar lights, dome lights, a speedometer light and an electric horn connection. It will be noticed that the return circuits are through the frame with the exception of the connections between the storage battery and the starting motor.

First we will trace out the flow of current when the starting switch is closed, this circuit being shown by the heavy black lines. Current flows from the plus terminal of the storage battery out through wire A to the motor, where it passes through the series field and the armature and from thence through the wire T to the starting switch and from there through the wire C to the negative pole of the battery.

Below 9 or 10 miles an hour or when the motor is at rest the cutout is open and therefore current for the lights must be furnished by the battery, and its path is as follows: It runs out through

wire A to one terminal of the starting motor, where it goes to the frame through the ground wire Z. From thence it runs to the lamps. From the lamps the current passes to the junction switch, where all the lamp terminals are connected to the terminal P, and from here the current flows through the series field of the generator and on out through wire F to a terminal on the cutout, and from thence to the ammeter over the short wire E. From the ammeter it goes via wire D to a binding post on the starting switch, from which it connects with the other pole of the battery by wire C. At or over 12 miles per hour the cutout contact points are closed as previously described. Current is then supplied to the storage battery if it needs charging and also to any [illegible] the lamps that are in circuit.

If the battery needs recharging it is of [illegible]rse below the voltage of the generator and therefore current wil[illegible]ow to it until its voltage becomes equal to that of the generator, when the flow will automatically stop because the electrical pressure at the two points is the same. The current passes from the positive terminal of the generator through wire G to the series coil of the cutout and from thence through wire Y to the frame. It flows through the frame up through wire Z to one terminal on the motor and from thence through wire A to the plus pole of the battery. The return circuit is through wires C and D to the ammeter and from thence through wires E and F back to the generator. The flow of current from the generator to the lamps is as follows: Through wire G and the series coil of the cutout and wire Y to the frame. This part of the circuit is identical with that for charging the storage battery. Then the current goes through the frame and up through the ground wires to the lamps, from whence it passes to the terminals on the junction switch and on through wire P to the generator. It will be noted that the generator and battery circuits to the lamps are independent, so that should anything happen to the battery, the lights could be operated by the generator alone. Diagrams of Gray & Davis 1915 systems will be found on folding plate, Fig. 307, in both non-technical and technical form.

A number of parts comprising the 1915 Gray & Davis starting system is shown at Figs. 308 and 309. The construction of the

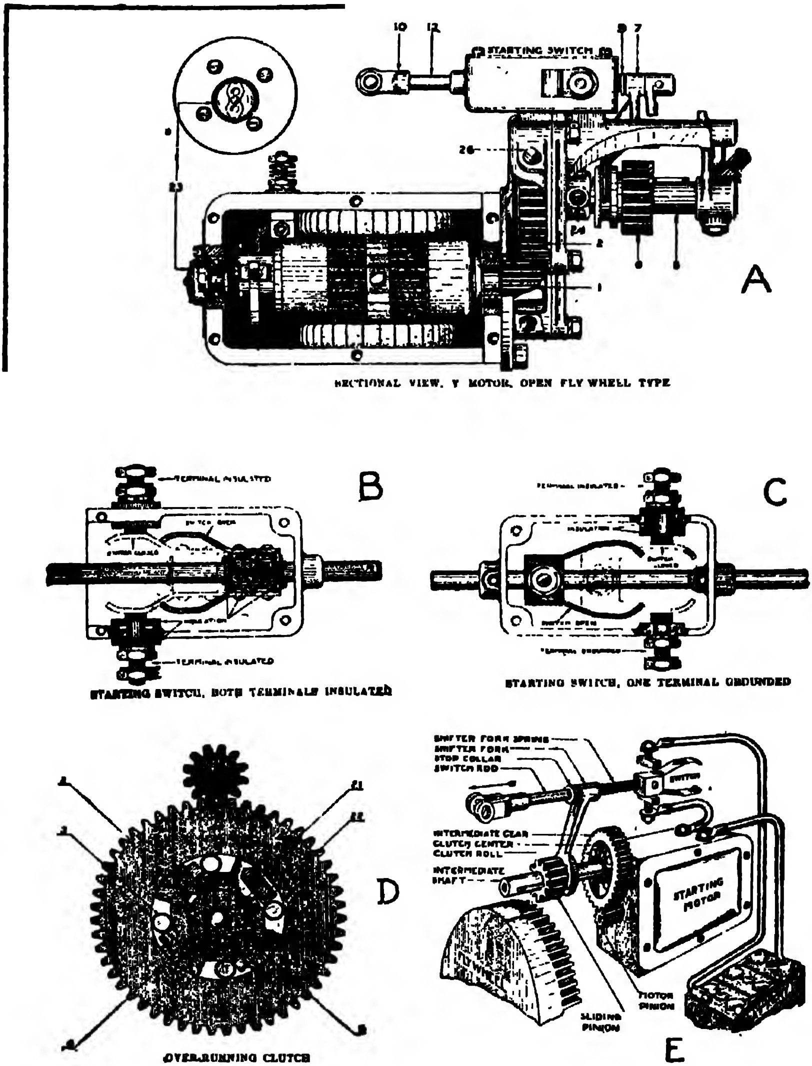


Fig. 308.—Starting Motor and Switch Details Used in 1915 Gray & Davis Starting System.

type Y motor used in connection with engines of the open flywheel type is clearly shown in the part sectional view at the top of the illustration. As the Gray & Davis systems may be had in either the one wire or two wire type, two forms of switch are provided. One of these, which is shown at B, Fig. 308, is used in a two wire system and has both terminals insulated. This must be wired up as shown at E. The heavy leads from the storage battery are connected as indicated. One of the storage battery terminals is connected to the terminal on the starting motor, while the other starting motor terminal wire goes to one of the insulated switch terminals. The other insulated switch terminal is connected directly to the remaining storage battery terminal. When used in connection with the one wire system the starting switch has one terminal grounded, as shown at C.

The approved arrangement of the starting switch is as depicted at the top of the illustration, in which the contact is not established until the sliding pinion has been meshed with the gear of the flywheel. The construction of the overrunning clutch used with the Gray & Davis system is shown at D. This functions the same as the overrunning clutch previously described, the drive being secured between the member 4, which is keyed to the intermediate shaft, and the reduction gear 2, which is turned by the motor pinion 1 through the medium of the clutch rolls 3. Light coil springs are employed to push plungers, designed to make more positive the engagement of the rolls of the overrunning clutch.

The fuse block, which is an important adjunct of the one wire system, is combined at the rear of the lighting switch, as shown at A, Fig. 309. The function of the fuse is to burn out should an overload occur in any circuit due to damaged insulation. The fuses are readily renewable, these being shown at D. The fuse consists of a glass tube, which contains a piece of fusible alloy wire that joins two metal caps, these caps being used to establish contact with the clips on the sides of the connectors at the back of the switch. The fuses should be handled carefully, and in removing same for examination it is well to do this with a sharp piece of wood, which is used as a pry back of the fuse instead of attempting to remove them with pliers or a screwdriver, which may break the

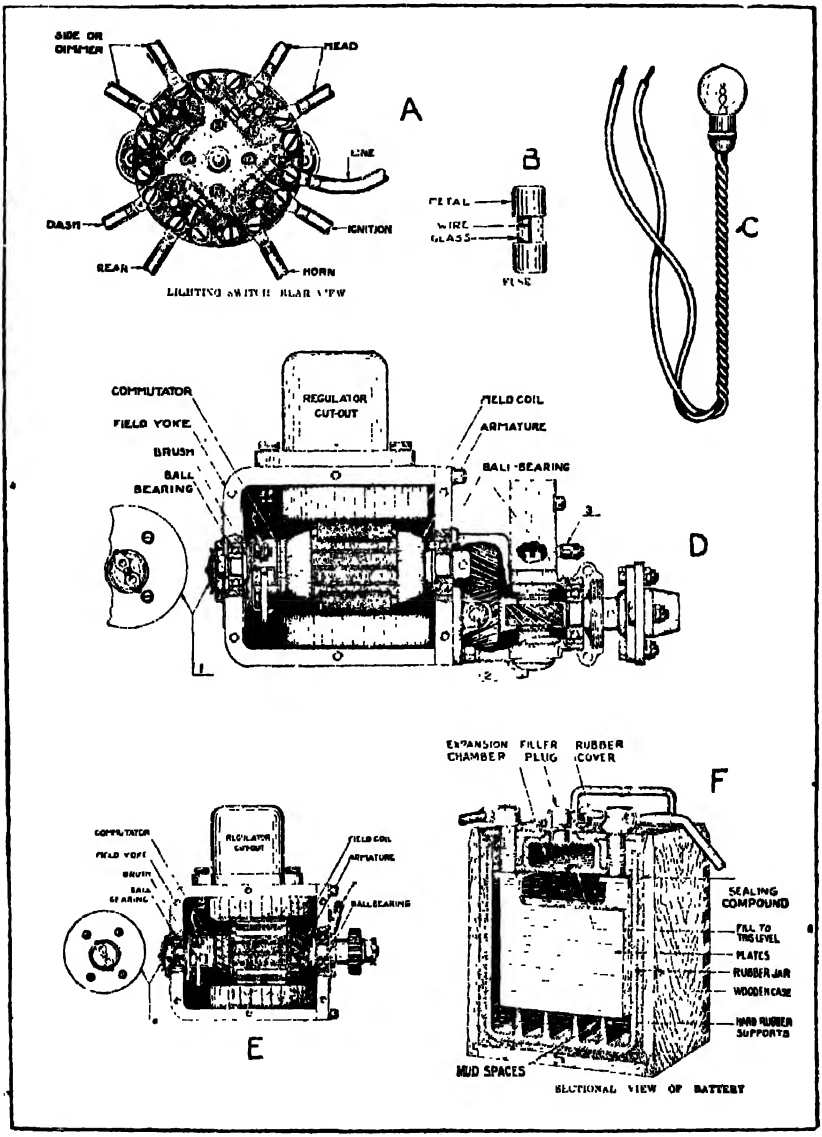


Fig. 309.—Generator and Battery Construction Used in Gray & Davis 1915 Lighting and Starting System.

glass or otherwise damage the fuse. An important adjunct to assist in locating trouble is a six volt lamp, such as shown at C. This is of material assistance in tracing circuits.

The latest form of Gray & Davis dynamo, which dispenses with the centrifugal governor used on the other types illustrated, is shown at D, supplied for direct drive by an extension of the timing gear shaft and for chain drive at E. The dynamo shown at D is provided with gearing to drive a timer distributor for ignition purposes. The current supply is governed by the regulator cutout, which performs two duties in the new systems. One of these is to regulate the dynamo to secure uniform current output, while in the other instance it connects the dynamo into the system only when sufficient current is generated to charge the battery. Current regulation is provided by short circuiting or shunting field resistances or to insert the field resistances into the field circuit. The object of the field resistance is to retard the flow of current in those windings. When the dynamo is at rest the cutout points are opened and the regulator points closed. As the dynamo first speeds up the regulator points remain closed and the field resistance is short circuited. This permits the dynamo to build up its full field strength. When the proper voltage is reached the cutout points close, permitting current to flow through the series winding to the system. As the dynamo speed increases beyond that necessary for full output, the pull of the shunt winding attracts the regulator armature. This reduces the pressure at the regulator points and inserts a resistance into the field circuit, this preventing further increase of output. The frequency with which the resistance is put into the circuit is in proportion with the amount of speed variation. The form of battery used with the Gray & Davis system is shown in part section at F, Fig. 309. It does not differ materially in structure from types previously described.

Locating Troubles in Gray & Davis System.—In event of trouble with the Gray & Davis lighting system, the makers recommend a careful study of the symptoms, which will usually provide a guide to find the component at fault. The indicator on the dash shows positively any failure of the generator or any break in the wiring. If the indicator does not indicate "charge" when the en-

gine is speeded up but shows "discharge" when lights are turned on and the engine at rest, the dynamo or current regulator is not working properly. A common trouble is the dynamo brushes not sliding freely in their holders. If the dynamo is driven by friction belt this may be too loose to drive the dynamo at proper speed. If the indicator does not indicate "charge" with the engine speeded up and does not indicate "discharge" with the lights on and the engine at rest, one should look for an open circuit or loose connection in the battery wiring or for corrosion or looseness in the storage battery terminals. Sometimes the dynamo terminals may have loosened and imperfect contact exist at this point. Should the indicator show "discharge" with the lights turned off and engine at rest (providing that the indicator pointer is not bent), the insulation on lamp wires may be injured, this permitting contact with the frame, causing a short circuit. If the indicator indicates "charge" with the engine at rest, it is a positive indication that the pointer is bent.

If the charge indications are below normal with the engine running, it may be on account of slipping of the driving belt if the dynamo is driven in that manner, or because of poor adjustment of the centrifugal governor, if that type of dynamo is used. If the ammeter "discharge" indications are above normal it is a sign that the lamp load is excessive or one of the lamp wires is in contact with the frame. When the indicator pointer jerks from one reading to another with engine running at constant speed on the discharge scale, it means either a short circuit in the system or a loose terminal. If trouble is experienced from fuses burning out repeatedly, it is a sign that the lamp wires are in contact with the frame at some point or that one of the lamps is defective because of a short circuited filament. If the engine cranking speed is very low and this is not due to the engine being stiff, such as would be the case in cold weather or after the engine has been overhauled and bearings tightened, it may be considered a positive indication that the storage battery is almost discharged or that it is defective in some way. If the starting motor does not rotate; the battery may be discharged, the starting switch may not be making good contact or a motor brush may not make good contact with the com-

mutator. There may be an open circuit in the battery wiring to the motor, or there may be a poor circuit or contact because of corroded battery terminals. If the starting motor rotates but does not crank the engine, it is a sign that the overrunning clutch does not work properly or that the starter pinion is not properly meshed with the flywheel gear.

If the lamps will not light but the starter cranks the engine, this shows that the storage battery is in proper condition and that the trouble is due to burned out or broken lamp filament or defective lamp fuses. If the lamps burn brightly but fail to illuminate the road sufficiently, the bulbs may be out of focus in respect to the parabolic reflector of the lamp or the lamp supports may be bent in such a way that the rays of light may be directed too far upwards. If the lamps burn dimly or not at all and it is difficult to crank the engine with the starting motor, this means a weak or discharged storage battery. In addition to this, the lamps may be old and have blackened insides, the system might be slightly short circuited, or considerable resistance may be present, due to loose or dirty connections. If the lamps blacken or burn out quickly they are not of the proper quality if they are six volt lamps, and not of the proper voltage if other than six volt lamps. There is one exception to this rule, and that is the bulbs of the tail lamp and dash light, which are three volt lamps when these two are wired together in series. Burning out of the lamps may be caused by the regulator not working properly, and if this is the case the lamps will burn out at high engine speed. If the lamps flicker and the ammeter or indicator needle is unsteady, look for loose connections in the light wires, loose connections between battery and dynamo, loose contact at a lamp connector or lamp bulb, poor contact between fuses and fuse clips, or an exposed wire touching the frame intermittently.

If one suspects that the battery is discharged, its condition may be readily determined by using the test lamp, shown at C, Fig. 309. The test lamp may also be used for locating short circuits or open circuits. It is well to bear in mind that the lead terminals of the battery should be scraped clean and bright at the point where the test lamp wires bear in order to insure a good clean contact.

If the test lamp burns brightly it shows that there is current in the storage battery. To locate a short circuit the fuses are removed from the rear of the switch and the wire is disconnected from the negative battery terminal. Connect one of the test lamp terminals to the free battery terminal and touch the other test lamp wire to the frame of the car. The test lamp should light if good contact is made, this indicating that the positive battery terminal is properly connected to the ground. Keep one test lamp wire in contact with the negative terminal and touch the other wire to the end of the battery wire just disconnected. If the test lamp lights it shows that a conductor or wire connected to the battery, lamps, horn or starting motor is in contact with or grounded to the frame of the car.

Any wires having injured insulation should be wrapped with electrical tape to prevent metallic contact between the conductor and the frame. Open circuits are best indicated by feeling of the wires where they fasten to the terminals to make sure that positive contact is made and that the terminal binding nuts are not loose. Short circuits may also be located if no test lamp is available by following the various wires and if any of these are found in contact with the frame, it is a wise precaution to pull them away and to wrap the section that was in contact with the frame thoroughly with insulating tape. If one lamp flickers and the rest burn brightly, look for a poor connection between the lamp and the lamp connector, a loose terminal at the junction switch or a defective fuse. If all lamps flicker, look for loose connections in wiring between battery and junction switch. When lamp bulbs have been renewed in head lights it is sometimes necessary to refocus the lamps. Head lights should not exceed 15 candle power, and should always be of the high efficiency filament type. Cheap carbon filament lamps will not only consume undue current but will not prove enduring. Tungsten filament lamps are best.

Chalmers-Entz System.—This is used on the Chalmers Model 26 and is shown at Fig. 310. It comprises a motor-generator, battery, switch and regulating device. The feature of the installation is that it prevents the gasoline engine from stalling, even when the car is in gear. For all normal driving the dash switch is left in the

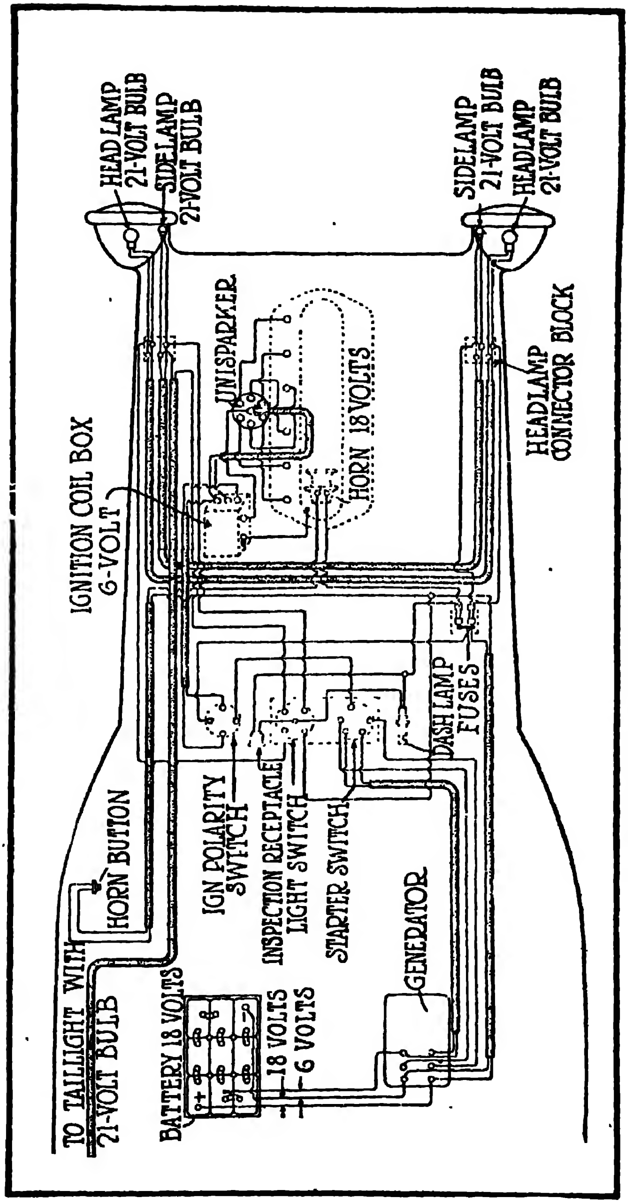


Fig. 310.—Wiring Diagram of Entz One Unit System.

position at the extreme right, or, in other words, the starting system is constantly connected with the motor. For constant driving at speeds in excess of 30 miles an hour the dash switch should be moved to the middle position in the slot. In this position the ignition of the motor is still operative, but the generative portion of the starting system is cut out so that the battery no longer is being charged. When there is a tendency for the engine to stop the electric motor automatically picks up and turns the engine over until proper firing occurs.

When the dash switch is thrown to the on position, current flows from the battery to the motor-generator, which as a motor revolves at about 100 r. p. m. As soon as the engine attains a speed of approximately 600 r. p. m., 6 to 8 miles per hour, car speed, the direction of the current, due to the way the switch is connected to fields and armature is reversed and the electrical machine then becomes a generator, which in turn charges the storage battery. In the illustration, showing the wiring of the Entz system, the voltages of the lamps are shown. In the case of the head lights, the small bulbs incorporated are also shown.

Remy Two-Armature Lighting and Starting System.—The electric starting motor and lighting generator on Series AA National cars is the Remy Model 150 six volt system. The electric machine employs two separate armatures and two separate fields, the motor being superimposed upon the generator, although both are in one steel casting, making a neat, compact unit, familiarly dubbed a "double decker." The wiring diagram is shown at Fig. 311.

The two armatures are connected together by a train of gears and an overrunning clutch, so that the gears and motor armature are in operation only when the starting switch is pressed. Incorporating the reduction gearing and overrunning clutch of the starting-generator unit in an oil bath, insures silent operation during starting, as external gears and the meshing of the same are entirely eliminated.

The unit has only one drive shaft and is connected to the engine by an Oldham coupling. This allows of quick and easy removal from the engine for inspection if necessary, although large

inspection plates are provided on the unit itself, which is conveniently and accessibly located on the engine. Although the frame for the two units is a steel casting, the magnetic circuits are entirely independent, as may be seen from the illustration. The generator is shunt wound and is automatically regulated for constant current by a vibrator, which is mounted on the same base with the relay or electric cutout. The function of the regulator is to keep the output of the generator constant regardless of the

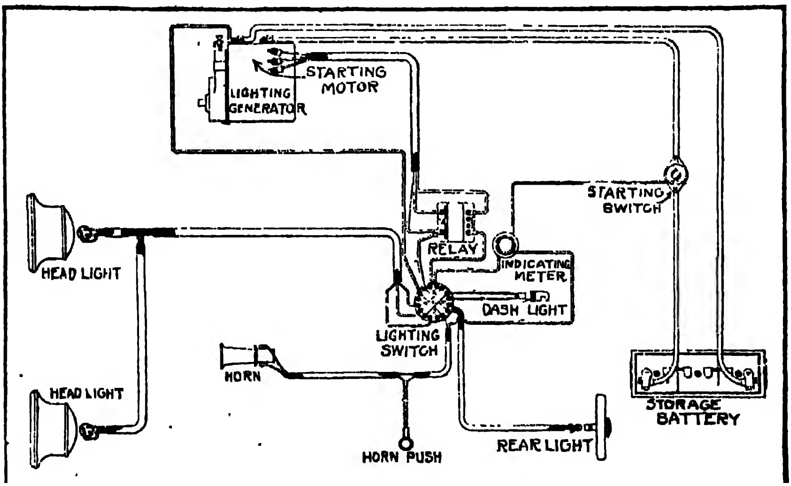


Fig. 311.—Wiring Diagram of the Remy-National Starting and Lighting System.

speed of the engine. The relay is simply an electric switch which opens and closes the circuit between the generator and battery automatically to prevent dissipation of battery current in the generator when the engine is at rest.

The motor is of the conventional series type and is wound to withstand heavy overloads. Armatures, brush holders, fields, etc., are built in accordance with standard electrical practice. The generator windings are protected against injury by means of a fuse located on the relay-regulator base. Should the battery become

disconnected either through accident or neglect, this fuse will burn, thus protecting generator and field against excessive voltage, which would result if the field circuit were not opened.

To start the engine the operator presses the starting switch, which puts the motor armature into motion, engages the gearing and clutch, and turns the engine over. When the engine is running under its own power the clutch and engine are automatically disengaged and the unit operates only as a generator. The lamp load of the car is carried by the generator at about 12 miles per hour. As a "tell-tale" an indicator is employed, from which the operator may determine whether the generator is working properly. A simple lighting switch is used for turning on any combination of lamps. No side lamps are used, as the head lamps contain small independent bulbs for signal lamps. The two-wire system of wiring is used. It has been carefully developed, resulting in a very simple layout, as may be seen from the accompanying wiring plan of the system as applied to the six-cylinder National car.

Faults in Motors and Generators.—While every effort has been made by the manufacturers of electric starting and lighting systems to have the various units function as nearly automatically as possible, it will be evident that some attention will be needed by the various units. The generator should be looked over from time to time and should any carbon dust be worn from the brushes by the commutator and deposited in the lower part of the casing it should be blown out with compressed air. It is stated that an accumulation of this dust may result in a ground to the generator case or produce a short circuit between the brush carrier and case. If the commutator is blackened or rough it must be smoothed down with fine sandpaper while the armature is rotating. Never use emery cloth for this purpose. After smoothing down the commutator remove all particles of metal which may bridge across between the copper segments. The insulating material between the commutator segments should not be higher than the surfaces of the segment, and if any of it projects it must be filed down slightly lower than the copper pieces by using a small file.

The brushes are the part of the generator that demand the most attention and to which most of the troubles in devices of this kind

are due. They should be examined to see that they are in perfect contact with the commutator and that they do not stick in the brush holders. Any dirt or grease on the brush assembly should be removed. One of the most fertile causes of poor brush contact with the commutator is on account of insufficient spring tension. When examining the brushes care should be taken to see that these are maintained positively in contact with the copper segments. Care should be taken not to have the spring pressure too great, as this would produce rapid depreciation of the brushes and heating of the commutator. Brushes that have worn down till they are short must be replaced with new ones. When replacing brushes be sure that they fit the commutator surface exactly over the whole area of the end of the brush, and in all cases use brushes for replacement furnished by the maker of the generator. In some generators, shunt connections, which are called "pigtails," are used for connecting the brushes. If the new brushes furnished by the factory have these connections attached care should be taken to make the connection exactly the same as on the old brushes.

It is imperative that the commutator be kept clean, as any oil or grease on the segments will collect carbon dust and produce short circuiting. The brush holders should be entirely insulated from the carrying case, and if any of the insulating bushings, washers or plates are found defective they must be replaced with new ones. Should the battery or generator be disconnected for any reason, do not operate engine again until they are connected. Never run a generator unless connected to the battery. With the engine running and lamps burning, if the amperemeter hand stays at zero it indicates that the generator is producing exactly the same amount of current as the lamps are consuming. If the hand is on the discharge side of zero it means that the current-consuming units are burning more than the generator is producing. If the pointer is on the charging side of the scale it shows that the generator is producing more current than is being used by the lamps.

The starting motor is subject to the same electrical troubles as the generator is. These are grounds, short circuits, brush and commutator troubles. Defects in either the motor or generator drive are of a purely mechanical nature and can be easily located by any

competent repairman. The centrifugal governor used on many generators is not apt to give any trouble unless some of the parts fail or the action becomes clogged with oil and grease. If the springs tending to return the weights are broken or become weakened the generator will not deliver the proper amount of current because the drive will not be positive. Any accumulation of oil that will interfere with proper frictional adhesion between the clutch parts where a governor is employed will also result in failure to drive.

Faults in Wiring.—In the two wire system every wire, connector and socket must be insulated from the car and should not be in metallic contact at any point except at the terminal. It is imperative that all wires be insulated from each other and the car frame except at points where permanent connections are made. All connections should be soldered to insure positive contact and securely wrapped with insulating tape. The wires must be held securely by means of cleats of insulating material and must be mounted in such a way that there is no possibility of sharp metal corners or edges wearing through the insulation and causing grounds or short circuits.

All wiring should be protected from the rotting action of grease, oil and water, and when the wiring is run where these substances are apt to accumulate, the regular insulation should be supplemented by a conduit of insulating material such as circular loom or fiber tubing, or armored cable should be used. All wires should be so installed that there is no danger of interference between them and operating rods and levers. The abrasion of these members will wear through the insulation, and result in short circuits. Brass or copper terminal connections should be used at all points and no connection should be made by winding the strands of wire around the terminal. One or more of the strands may bridge across the terminal or to some metal part and cause a short circuit or ground. Special care should be taken with the connections in the lamps and other points. By the term "short circuit" electricians mean that two wires of opposite polarity are in metallic contact. Under such conditions the storage battery will be discharging and there will be no lights at the lamps. A short circuit may occur at any point

in the wiring system, but is usually found at terminals that have been carelessly made or by worn insulation on wires.

A short circuit will be indicated by the position of the amperemeter pointer. Always note the position of the index hand of that instrument when the car is stopped. With the engine at a standstill and no lamps burning the hand should point to zero. If it does not the amperemeter is either out of calibration or there is a leak of current from the battery at some point in the wiring. To ascertain if the amperemeter is correct, uncouple one of the battery terminals of the lighting system. Obviously, if the hand swings to zero, the trouble is leakage of current, which should be immediately corrected after the trouble is located. If the index does not point to zero when the battery terminal is disconnected, the instrument is out of calibration, and while this does not affect the operation of the system it should be taken into account when reading the amperemeter. If the engine backfires when the ignition is interrupted and it makes one or two revolutions in the reverse direction, the amperemeter pointer may be found at the extreme of the scale on the discharge side. This is caused by the circuit breaker contact being held closed and means a short circuit of the battery through the generator winding. This must be corrected at once by momentarily disconnecting one of the generator wires or starting the engine. If the wires are removed from the generator for any reason make sure that they are connected to the same terminals as they were originally. If the wires are reversed the amperemeter will indicate a dead short circuit by swinging to the extreme on the discharge side of the scale when the engine is started, and if this defective condition is not corrected the battery will be soon discharged. In case of a short circuit examine all of the wires connected to the battery terminals and to the lighting switch. Make sure that the insulation is perfect and that it has not been cut through at any point. Whenever any wires are removed from any of the units always mark the terminals and the wire so that they will be replaced exactly as they were originally. If a short circuit exists when all the switches are opened, if one takes off a battery terminal and makes and breaks contact between the wire and that member a small spark will be in evidence. If no sparking occurs,

connect up the terminal to the battery and then with the engine at a standstill close the switches to the lighting circuit one at a time and watch the amperemeter closely as each switch makes contact. If the pointer does not move far from zero it shows that the current consumption is normal; if, however, the pointer swings to the extreme of the discharge scale it is evident that a short circuit exists somewhere in the circuit just brought into action. All the circuits can be tried in this manner one at a time. If the amperemeter indicates only a normal amount of current consumption for the various lighting circuits it is apparent that no further search is necessary. If, however, the needle indicates a short circuit on one or more of the switch positions, examine the wires carefully for the circuits at fault, and if the trouble does not exist there it may be located in the lamp socket, the connector or the bulb itself. In case one or more lamps fail to burn the trouble is due to either a broken wire or a defective connection at the switch, connectors or lamp sockets or a bulb or fuse is burnt out.

The following instructions relative to the care of the lamps and storage battery of the Auto-Lite system are taken from an instruction book prepared by this company and apply to similar components of all systems. Complete directions for the care and charging of storage batteries are given in the preceding chapter, but at the same time a review of the important points to keep in mind in connection with the maintenance of the batteries used in lighting and starting systems will prove of value to the motorist or repairman who does not desire to go thoroughly into the subject of storage battery charging or maintenance.

To clean head and side lamp reflectors, remove from lamp body and carefully blow out any dust which may have collected on the reflecting surfaces. Then dip a small piece of absorbent cotton in alcohol and lightly wipe over the surface—always from the back to the front. To focus the lamps, open the swinging front of the lamp and direct the light upon some smooth vertical surface at a distance of about ten feet. Loosen the adjusting screw on the slide at the rear of the reflector, and move the bulb and socket out and in until all rings disappear in the illuminated area. Then tighten down the adjusting screw and close the lamp. Any further adjust-

ment of the lamp must be made by bending the arms of the lamp bracket with a heavy wrench until the light from each lamp strikes the road at the point desired.

Do not connect additional apparatus, such as electrical horns, cigar lighters, etc., to the system without taking the matter up with the factory. The surplus capacity of the system is large, but there is a limit to the amount of current which the generator can produce. Use the same judgment and reason in the operation of the electric lights on a car as you do those in your home or garage. When a car is running it is not necessary to burn all the lights, the two heads and the tail are all that are required or that are of any service. When the car is standing at night, use the side and tail lights only. When push type connectors are used, if halves of connectors are loose when pushed together, the contact will be poor. Spread the connector posts slightly so that they will slide in their sockets snugly. If Ediswan type are used, and plunger springs in connector do not operate, replace the connector with a perfect one.

The storage battery is made up of several hard rubber cells or containers for the active plates and liquid electrolyte. The whole is surrounded by a wood casing for mechanical protection and ease in handling. Each individual cell is provided with a screw cap for inspection and the addition of electrolyte or distilled water when necessary. (See Fig. 301 and Fig. 305, B). The electrolyte must at all times cover the tops of the plates at least one-quarter inch. Insufficient electrolyte will result in warped or buckled plates, and an accumulation of sediment at the bottom of the cells. The battery will be ruined in a short time if the tops of the plates are not kept covered. Each cell must be inspected at least once every week in summer and once every two weeks in winter. All screw caps must be removed and distilled water added to each cell to make up for the natural evaporation. If distilled water cannot be had use clean rain water which has not come in contact with metal or cement.

Never add acid to the cells of the battery. If part or all of the electrolyte has been lost through accidental spilling or leakage get full instructions and advice from the maker. An hydrometer, arranged with a rubber bulb to draw a portion of the electrolyte

from each cell, furnishes the best indication of the condition of the battery. The hydrometer shows the specific gravity of the electrolyte, which for a fully charged cell should be 1280 on a specific gravity scale. If the car is out of service for a considerable length of time, as when laid up for the winter, it is necessary to charge the battery at regular intervals. This may be done by running the engine at a car speed of twenty miles per hour for at least one hour every two weeks. If the car is to be stored, and it is not convenient to charge as above, the battery should be removed from the car and placed in a reliable garage to be properly taken care of.

If your battery is arranged with terminal posts for the wiring connections these must be examined occasionally to see that they are clean and free from sulphate. The thorough application of a small amount of vaseline at the metal connections to the battery posts will prevent sulphating and consequent corrosion and poor electrical contact at these points. If the electrolyte leaks from the joints, bottom, or wood sides of the battery case, one or more of the hard rubber cells are cracked or broken. The battery must be returned to the factory for repairs or replacement. The metal battery box must be thoroughly wiped out with a cloth saturated with ammonia to neutralize the acid and prevent corrosion. The top of the battery must be kept clean and dry to prevent a leakage of current between the terminals. See that the battery is held securely in its metal box or other container. If necessary pack tightly with waste to prevent the battery shaking about from jolting of the car. Tools, other metal articles, or anything of value should not be placed near the battery as the acid fumes will corrode and destroy metal, cloth and like material. Make certain that the battery terminals cannot touch the cover of the metal battery box. A thin sheet of wood fiber fitted inside the cover of the battery box will prevent short circuits or grounds from this cause. It must be remembered that the efficiency of any storage battery decreases with drop in temperature and it is only about 50 per cent. efficient at zero temperature. For this reason the demand for current should be kept as low as possible in cold weather and lamps turned off when not needed.

The user of any electrical starting and lighting system will

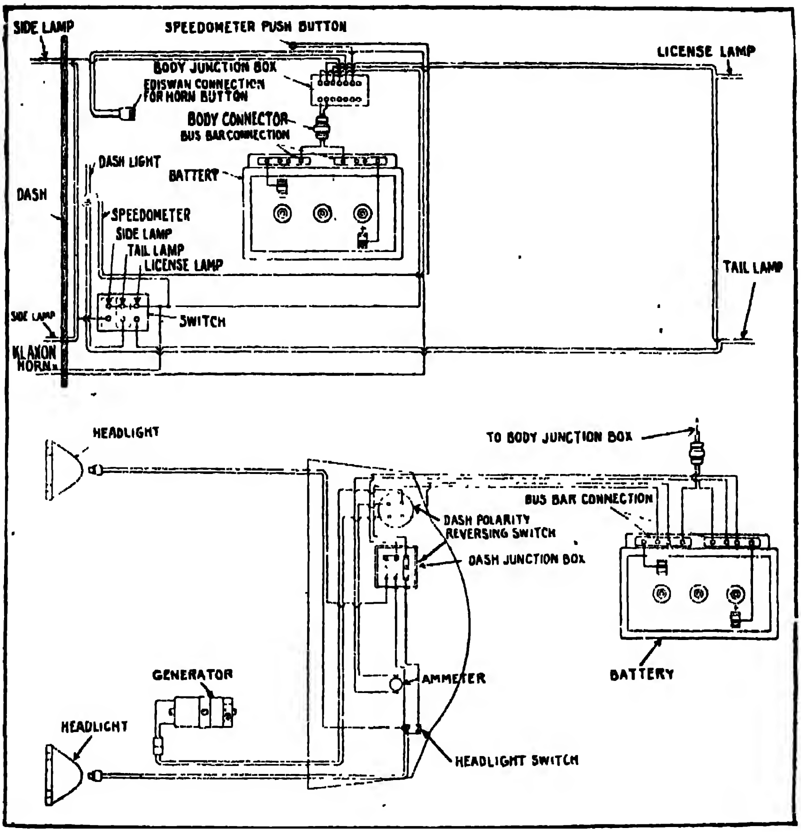


Fig. 312.—Wiring Diagram, Showing Typical Lighting System.

avoid trouble and expense by the observation of the following instructions:

Don't replace worn-out brushes with any others than those supplied by the manufacturer.

Don't put oil or grease on the commutator of the generator or motor. No lubrication is wanted there.

Don't turn the hose on the generator or motor when washing your car.

Don't tighten up on the silent chain drive unless the slack be-

comes excessive from stretching. The chain must be run w. our reasonable amount of slack to prevent noise and wear. ni

Don't fail to lubricate the silent chain drive at frequent intervals. Noise will be eliminated and wear reduced. Keep the chain and sprockets clean, and free from dirt and gravel.

Don't run your car, if for any reason the battery is disconnected from the circuit, unless you have disconnected the chain driving the generator, or the generator itself has been removed.

Don't attempt to propel car with starter. Such "stunts" are interesting, but expensive. Gasoline is for that purpose.

Don't attempt to make adjustments of any kind in the circuit breaker.

Don't fuss with the system when it is operating properly.

Typical Lighting System.—In order to show clearly the wide use that is made of electric current, even on cars not provided with an electric starting motor, wiring diagrams are shown at Fig. 312 which represent the frame and body wiring of a Packard touring car without starting motor. This wiring is used solely for conveying battery current to the lamps and other current-consuming units, which includes a Klaxon horn and speedometer light in addition to the usual lighting equipment of six lamps. Two rear lamps are provided, one of these the usual red signal specified by law, the other is a white light used to illuminate the license tag. In order to make it possible to remove the body from the chassis without destroying the wiring, the current conductors are run in two independent groups, one being secured to the body, the other running through suitable conduits attached to the frame. The upper view shows the body wiring with the storage battery connected, though this member is carried by the frame and has a connector which may be readily broken when desired to join the battery with the body junction box. Among the appliances carried by the body may be mentioned the side lamps, the speedometer and dash lights, the Klaxon horn, and the two tail lamps. The arrangement of the wiring is clearly shown in the illustration, the method of running the wires from the junction box to the various units is clearly defined. Attached to the chassis are the two head lights, the storage battery, and the lighting generator. In th

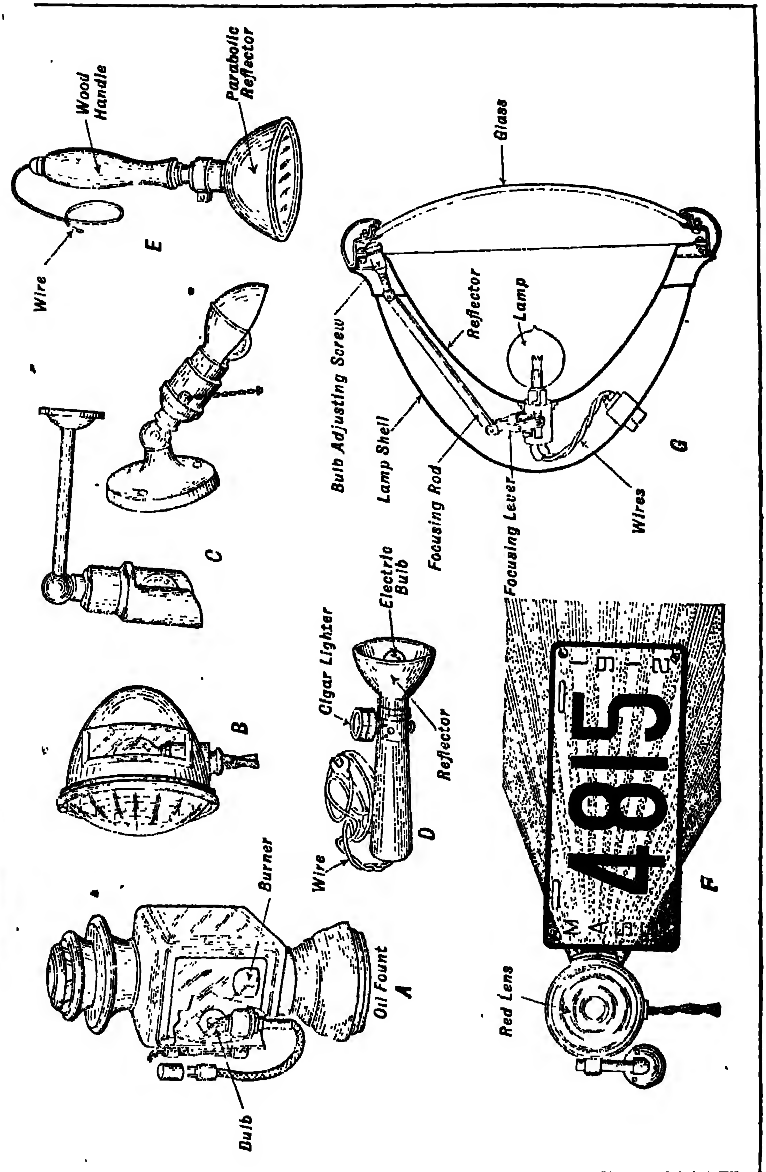


Fig. 313.—Group of Lamps Used in Connection with Electric Lighting System.

system the generator is used to charge the storage battery, the cur-rent going through the usual automatic cutout switch to prevent a reversal of current at such times that the generator is not supplying enough energy to charge the battery. As is true of the diagram presented above, all of the circuits are clearly shown and may be readily followed by any one.

The construction of the various forms of electric lamps used in motor car lighting systems is clearly shown in Fig. 313. The lamp outlined at A is a combination form, designed to use either kerosene or electricity, the former being used only in the event of failure of the latter. The side lamp at B is a neat form, intended to use electricity only. Dash, coil and speedometer lamps are depicted at C. A combination trouble lamp and cigar lighter is shown at D. The trouble lamp at E is an easily portable form and is convenient for use around the power plant, gasoline tank, etc., deriving its current from the regular battery. A combination tail lamp, having red lens at the rear and a white glass at the side to illuminate the number plate, is shown at F. The approved construction of a variable focus electric head lamp is shown at G.

CHAPTER VII

CLUTCH AND GEARBOX FAULTS

Principal Clutch Troubles Outlined—Cone Clutch Construction and Adjustment—Cone Clutch Repair—Plate and Disc Clutches—Band Clutches—Planetary Gearset Repair—Friction Drive Faults and Remedies—Troubles in Sliding Gear Transmission.

It is not difficult to locate defects in the power plant, as the symptoms resulting from faulty action of the engine mechanism and the parts of the auxiliary groups are such that can be readily recognized by comparatively inexperienced repairmen. There are a number of points in the power transmission system that may depreciate in service and their faulty action will not be immediately discovered. There may be serious wear in the power transmission elements, such as the gear box and the rear axle, which will mean a serious diminution in the amount of power delivered to the rear wheels. As these faults are usually of a purely mechanical nature, they are not generally known, and as a rule only show up in a positive manner when a car is overhauled thoroughly.

Principal Clutch Troubles Outlined.—The first member of the power transmission system to be considered is the friction clutch in its various forms, and it is important that clutch troubles be readily recognized, as the power, capacity and speed of the entire vehicle will be affected if the clutch action is not as it should be. Considering first the general troubles which are apt to materialize with all types of clutches, we will consider as the most important a too sudden or harsh engagement, which causes "grabbing," failure to transmit the entire engine power, lack of capacity due to failure to engage properly and poor or slow release, which results in "spinning." Clutches that employ frictional material as a facing will not act properly if the material becomes worn or if it

is glazed over. Besides the trouble due to defective friction members, there are other portions of the clutch mechanism that demand care and inspection. As the cone clutch is the most common, we will describe the construction of a typical clutch of this nature and then consider the methods of repairing defects that may materialize in service.

Cone Clutch Construction and Adjustment.—The cone clutch assembly shown at Fig. 314 is that used on National automobiles and is one that has given excellent service. The female member is machined in the flywheel rim while the male member, from which the clutch type takes its name, is a truncated cone or saucer-shaped

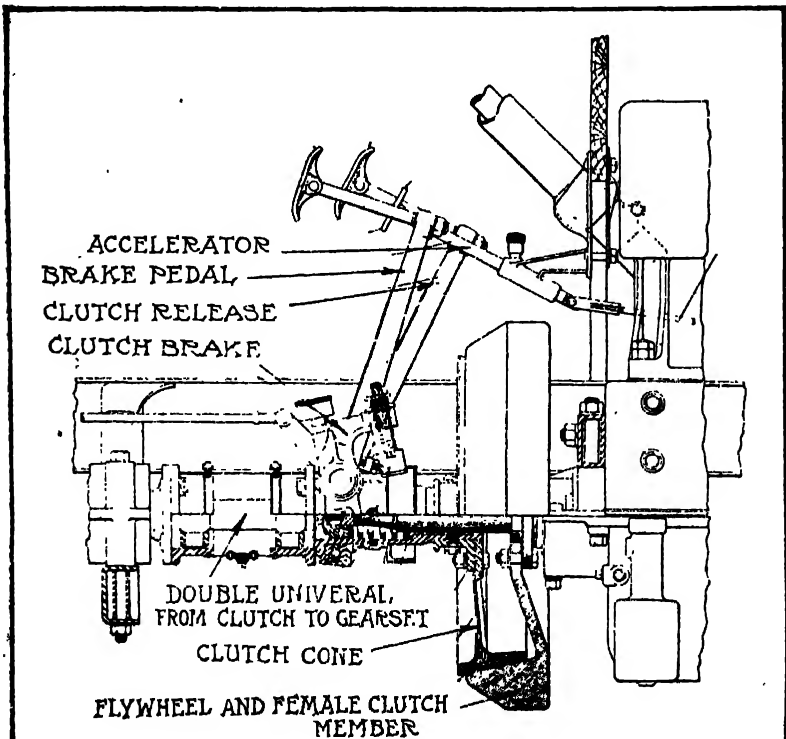


Fig. 314.—Clutch and Control Pedal Assembly of National Automobile.

member cast of aluminum, which has a friction facing of leather. The clutch cone transmits power by virtue of frictional adhesion with the flywheel rim, this amount of friction being increased by the wedging action due to the angular face of the clutch members. The pressure maintaining the parts in engagement is produced by

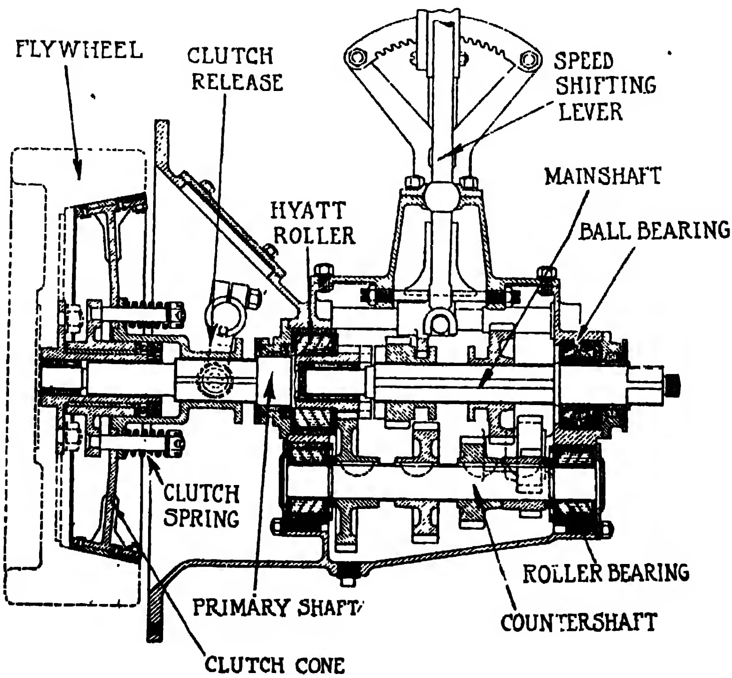


Fig. 315.—Sectional View, Showing Gear Box and Clutch Assembly, Forming Part of Unit Power Plant.

a substantial coil spring carried by the flywheel extension, this spring exerting its pressure against the cone-carrying member and having its reaction absorbed by an anti-friction bearing of the ball form. The power from the clutch cone carrier is transmitted by a double universal joint to the gearbox, placed back of the clutch and about midway on the chassis frame.

The views of the National chassis presented at Fig. 339 will show the relation of the clutch and gear box in the National car very clearly. When it is desired to interrupt the engine drive the clutch release pedal is depressed, this pulling the clutch cone carrier so the cone is pulled away from the female clutch member. In order to prevent "spinning" and make gear shifting easy, as soon as the clutch cone is fully released a friction brake interlocked with the clutch pedal is brought in contact with a small brake drum member, which retards clutch movement. Another form of friction clutch, showing its relation to the gearbox of a unit power plant, is clearly outlined at Fig. 315. This is of Covert manufacture and will be found on a number of 1915 automobiles. When the clutch and gearset are incorporated as a unit the design of the engine is such that the gear box is bolted directly to the engine crankcase in order to obtain a unit power plant. In this cone clutch the spring pressure maintaining contact between the male and female clutch members is produced by four coil springs carried outside of the clutch cone, where they may be easily reached through the clutch case cover when it is necessary to increase their tension.

It will be apparent that as the clutch facing wears and the cone seats itself deeper into the female member that the spring tension may be reduced to some extent. In the clutch shown the spring pressure may be increased as desired by pulling out the split pins that keep the castellated adjusting nuts from turning and screwing each of these members in the same amount, endeavor being made to have the tension of all springs as nearly equal as possible. The clutch springs exert their pressure against the clutch cone at one end and the reaction is taken through the stud to a spider member between the clutch cone and the flywheel, which bears against a ball thrust-bearing carried by the crankshaft extension member bolted to the flywheel, as indicated. When it is desired to release the clutch, the pedal rocks a shaft to which a yoke member is fastened. This yoke member carries rolls which bear against an upturned flange on the clutch cone carrier, which also transmits the power of the engine to the squared end of the primary shaft. The construction of the gear box will be described in proper sequence.

The clutch shown at Fig. 316, A, is used on models B-24 and

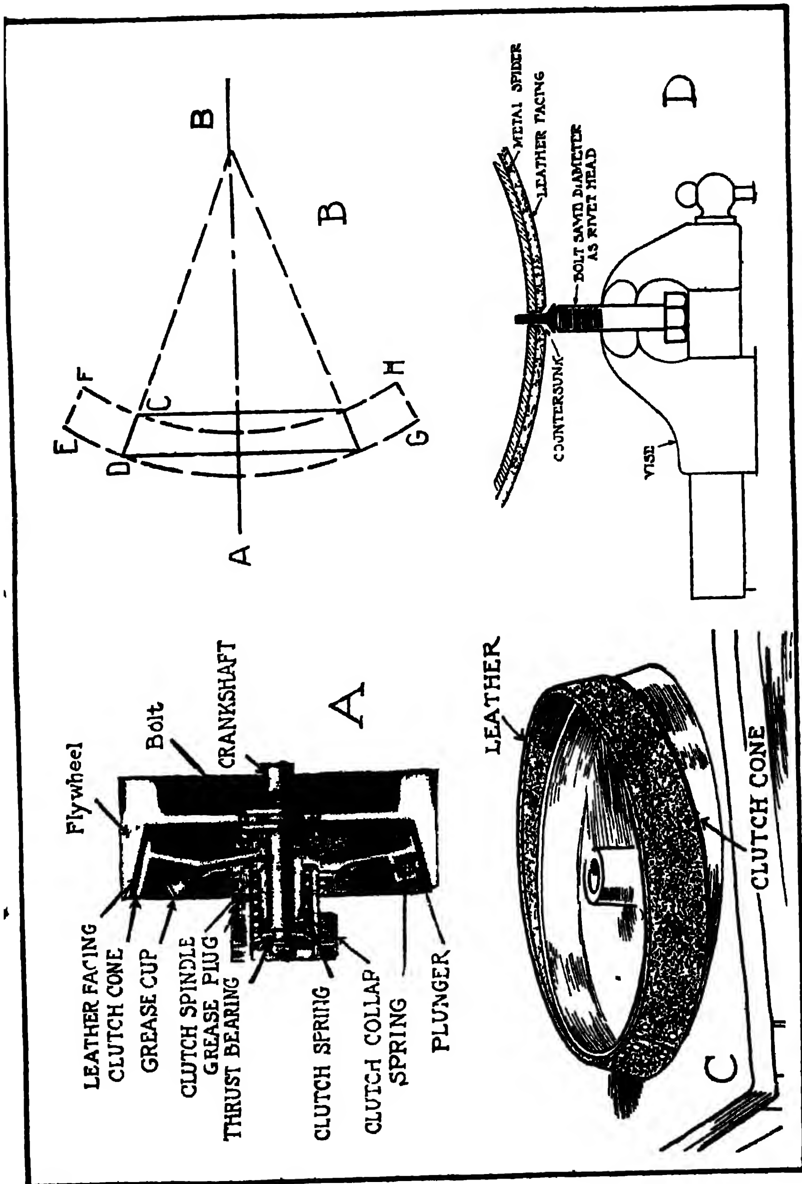


Fig. 316.—Processes Incidental to Refacing Clutch Cone Outlined.

B-25 Buick cars. It is of the leather-faced cone type, having three plungers pressed against a leather facing by coil springs to make for easy engagement. The construction is clearly shown in the accompanying sectional view, which also points out the portions needing lubrication. Of these, the clutch spindle is lubricated by a grease cup carried by the clutch cone, while a pipe plug is placed in the spring housing to introduce grease for the thrust bearing. In this clutch the spring tension may be increased by screwing in the threaded nut on the end of the crankshaft extension. The clutch cone is of aluminum and is tapered in the usual way, having a standard angle of 12½ degrees. The cone is held in engagement with the flywheel by the large coil spring enclosed in a housing member, that also serves as a clutch cone carrier. At the rear of this sleeve or housing member is placed the coupling which connects the clutch with the primary shaft of the change speed gearing. The housing carries a collar connected with the clutch pedal, so that when that member is depressed the clutch spring is compressed and the cone pulled away from the flywheel rim. After the clutch has overcome the inertia imparted by the flywheel it remains stationary when released, the crankshaft extension rotating freely inside of the clutch spindle bearing.

The most common cause of faulty clutch action is some defect of the leather facing, as this may be packed down hard or charred by heat from slipping, or it may have been used so long that the leather has lost its life and become hard, with a glazed surface that has a very low degree of frictional adhesion. The clutch spring may have become weakened or broken; this will cause the clutch to slip, even if the leather facing is in good condition. The two troubles usually met with are harsh action as one extreme condition and power loss because of slipping as the other. If the surface of the leather lining becomes hard and does not have enough resiliency to yield slightly when first brought into frictional contact with a flywheel rim, this results in harsh engagement. To insure gradual clutch application the friction lining should be soft and elastic. If the leather has not been charred or is not worn too much it may often be softened by rubbing it with neatsfoot oil and allowing that substance to soak into the pores of the leather. Kerosene oil

is often enough to keep the clutch leather soft and pliable, and it has an added advantage in that it has so little lubricating value that the clutch members are not likely to slip because of reduced friction. Kerosene also has a quick penetration property that is valuable and does not collect grit or gum. Cylinder or machine oil should never be used to soften a clutch leather.

When a cone clutch slips and the friction facing is not worn or the spring tension is not lessened the trouble is usually due to a coating of lubricating oil on the frictional material, that reduces the friction so that the pressure of the clutch spring is not great enough to keep the clutch parts tightly pressed together in positive driving engagement. A simple remedy for this defective condition is to absorb the surplus lubricant by rubbing a small quantity of Fuller's earth into the leather surface. When a clutch cone is assembled it is not easy to reach the friction lining. The first step is to disengage or release the clutch and fasten the releasing mechanism in such a way that the clutch cone will stay out of engagement even when the pressure is released on the pedal. On some cars the clutch release and emergency brake applying mechanism are interlocked so that applying the hand lever will release the clutch. The clutch may be held out of engagement in this case by latching the emergency brake lever. The Fuller's earth is placed on a piece of paper or card so it can be sprinkled into the space left between the male and female members. Powdered borax is often recommended for the same purpose. Rosin is sometimes advised, but this material should not be placed between the clutch members, as if there is any tendency to slipping and any generation of heat it may be melted and will become a lubricant that will intensify the slipping instead of acting to absorb the oil, as the Fuller's earth or borax will.

If slipping is caused by a broken clutch spring, which is a very rare occurrence, or by weakening of the clutch spring, which is more common, the method of repair is evident, this consisting of substituting springs of proper strength where no adjustment is provided or by increasing the degree of compression of the weak spring if some method of compensation for shortening the spring is provided. Another annoying condition when a cone or three-

plate clutch is used or where the clutch-driven members are of large diameter and have considerable weight, is "spinning" or continual rotation of the male clutch member when the spring pressure is released. This is often due to inertia, but is sometimes caused by a defect in the clutch mechanism. If the bearing on which the cone revolves when disengaged is not properly lubricated or if a poor grade of grease is used for this purpose the bearing may stick and the male clutch member will continue to rotate, even when the spring pressure is released. The ball thrust bearing employed to take clutch spring reaction, and which is clearly shown in the various sectional views previously described and in Fig. 318, which shows a cone clutch partially dismantled, may become wedged by a broken ball or particles of foreign matter, and if rotation of the parts relative to each other is prevented the rotation of the crankshaft will be imparted to the cone member through the clutch spring, which must turn with the crankshaft instead of remaining stationary, as would be the case if the ball thrust bearing were functioning as it should.

A seized clutch spindle bearing can only be repaired by taking the clutch apart and dressing down the scored journal, supplying a new bushing and removing the cause of the seizure. Sometimes when the clutch cone is carried on plain bearings wear in these members will permit the cone to sag because of its weight, and even though the spring pressure is fully released the lower portion of the cone will come in contact with the flywheel and the cone will be kept in rotation. Faulty clutch action is often traced to points distinct from the clutch mechanism itself. This applies to all types of clutches. Many cases of failure of clutch to release have been found due to imperfect relation of interlocking levers or rods or depreciation in some mechanical parts. If the clutch shifting collar is worn unduly or the small pins in the rod yokes connecting the clutch pedal with the release mechanism have worn, the pedal may be fully depressed and yet the pressure of the spring keeping the parts in contact may not be reduced to any extent. Where the emergency brake lever is interlocked with the clutch release leverage it may be possible that an adjustment of the brake rod, if these are shortened to compensate for wear of the brakes, will

change the length and may throw out the clutch mechanism slightly and cause slipping of the clutch because the spring pressure may be partially relieved.

The clutch release mechanism used on the Overland car as well as the provisions for adjusting the clutch spring are clearly shown at Fig. 319. When the clutch cone facing wears the only remedy is to dismantle the clutch, as shown at Fig. 318, which permits one to remove the old clutch lining from the cone and rivet a new one

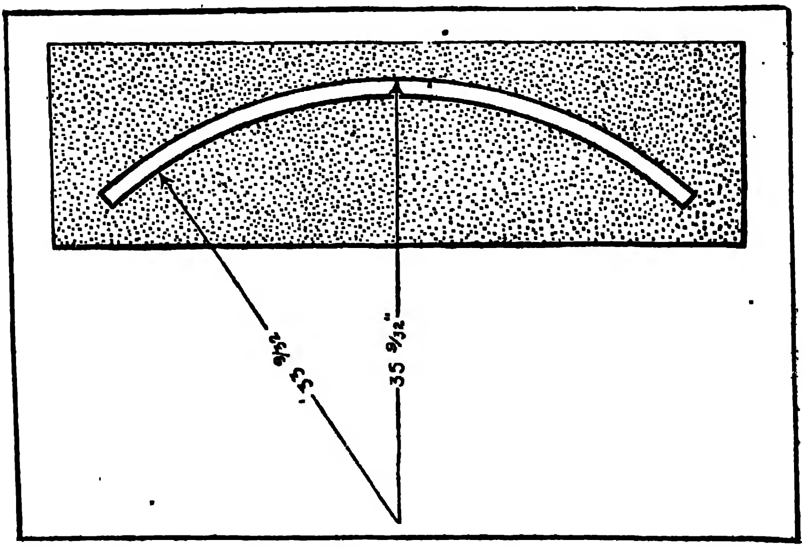


Fig. 317.—Pattern for Cutting Clutch Leather for Overland Model 80 and 81 Cars.

in its place. If the old facing can be removed without breaking, it may be employed as a pattern or basis for a new lining. If the car is a model of standard make and recent manufacture the best plan is to obtain a new clutch facing from the manufacturer. However if the car is an old model or if the facing must be put on immediately it is not difficult to lay out a clutch leather that will go in place without difficulty.

The first step is to lay out the clutch to exact size on heavy

drawing paper, making sure that the faces are at the proper angle. This may be done as shown at Fig. 316, B. Draw a long line through the center of the clutch cone and parallel with the hub; this being represented by the line AB in the drawing. Continue the angle of the cone by straight lines, meeting at a point in the center line. Using this point as a center and the distance from B to C and B to D as radii, describe the arcs of circles EG and FH. The distance from E to G must equal the larger circumference of

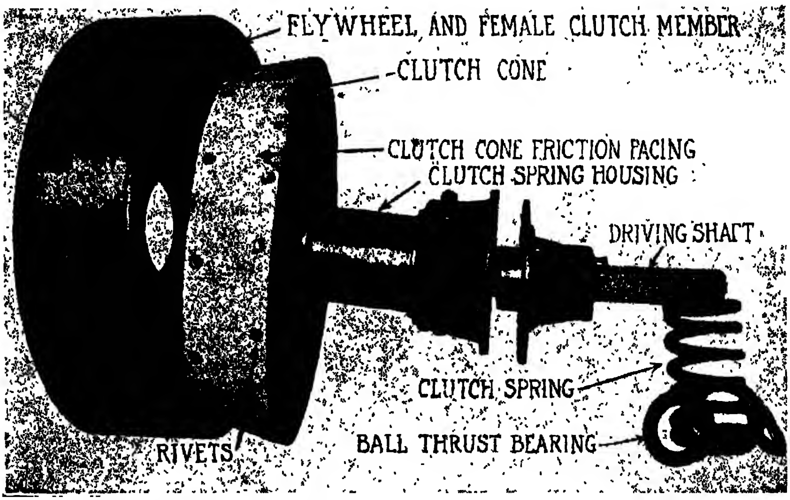


Fig. 318.—Cone Clutch Partially Disassembled to Show Important Components.

the cone so the ends will butt together, or it may be advisable to make the strip somewhat longer than necessary to allow for fitting. The pattern thus obtained may be used to cut the new leather. A special friction leather which is made for this purpose should be used. The thickness of the facing is important, because if it is too thick it will prevent the cone from entering the flywheel as it should. The clutch leather is usually one-quarter inch thick.

Before riveting the leather in place it should be made as pliable as possible with neatsfoot or castor oil, though all repairmen are not in agreement regarding this practice. Some advocate soaking the

leather in water and applying to the cone wet so that when it dries it will shrink and hug the cone closer. Others apply it dry and oil it after it is placed. In the opinion of the writer, which is based on considerable experience, letting the leather shrink is likely to result in the friction facing pulling away from the rivets, while oiling the material after application is apt to cause expansion and an uneven surface. When the leather is oiled before application it is soft and pliable and there will be no trouble in the material becoming loose from its fastenings if it is properly fitted. There are two methods of fitting the

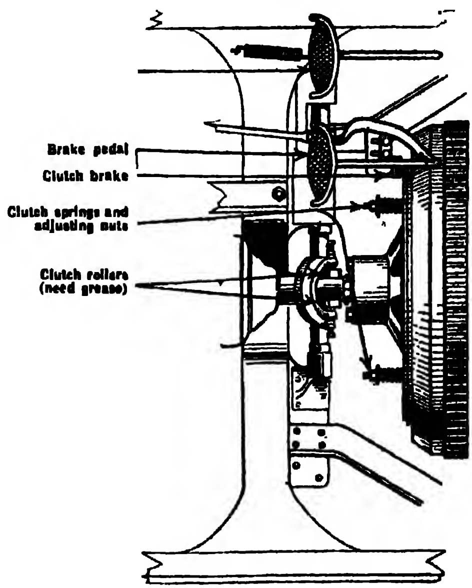


Fig. 319.—Clutch Control Assembly of Overland Automobiles.

clutch leather. One of these is to attach the leather at one end, holding it on the cone with a machinist's clamp or hand vise, while the holes are then drilled in the leather to coincide with those in the cone. The two holes at the extreme end are first drilled and the leather riveted in place, care being taken that the holes for the rivet heads are countersunk deep enough so the copper will be well below the surface of the leather. After the end is securely fastened the leather is pulled tightly around the cone to the next point of fastening, the facing again being retained by clamps while the holes are drilled and the rivets applied. This operation is repeated from one point of attachment to the next. This method insures that the facing will hug the cone closely instead of standing away from be-

tween the rivets, as is sometimes the case when all holes are drilled in the leather before application, which is the alternative method.

After a facing is applied it should be trued in a lathe by taking a light cut off its surface or the high spots may be rubbed off by hand with sandpaper, a piece of glass or a coarse file until a a full bearing is obtained all over the clutch facing. The material ordinarily used is good oak bark tanned belting leather, though hemlock and chrome tanned leather have been used with good results. The oak tan seems to possess all the desired qualities of elasticity, durability and degree of frictional adhesion required. The other method of applying the leather is to rivet the two ends to the cone as shown at Fig. 316, C, and then to pull the leather in place and rivet at the point directly opposite that where the two ends are riveted. The other rivet holes are then drilled to correspond with those in the cone. It is not desirable to cut woven wire asbestos fabric, and when this material is used it must be obtained all ready woven to form from the car manufacturer. Special copper rivets are used for riveting the friction facing to the cone. These have broad, flat heads of medium thickness, in order that they will keep the leather firmly in place without danger of pulling through, as would be the case if the rivet heads were small. Care should be taken to countersink deep enough for the rivet heads so that these will not touch the female member until the leather is worn so much that it needs renewing.

It is not difficult to do a good job of riveting if a bolt or punch the same diameter as the rivet head is used as a support, as shown at Fig. 316, D, and the end of the rivet is burred over with a rivet set, or with the ball pein end of a machinist's hammer. The punch supports the head of the rivet and forces it positively into the countersunk hole and insures a good tight fit. On some clutch cones, notably that used in models of the White automobile, the friction facing is held on the cone by means of T-bolts, which fit into depressions cast into the cone spider. Renewal of the leather is a simple matter, as the worn facing may be removed by loosening the clamping members and a new facing easily applied. The method of making a pattern for the clutch leather of some of the Overland car models is clearly shown at Fig. 317.

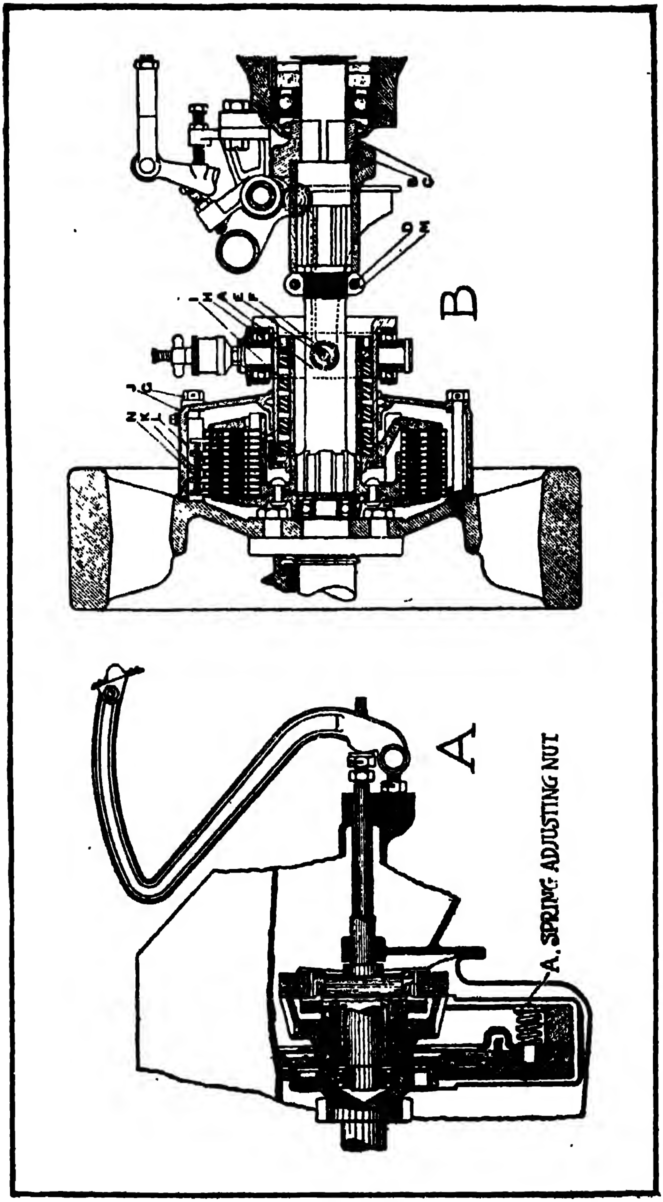


Fig. 320.—Showing Clutch Construction of 1914 Hupmobile at A and Multiple Disc Clutch Used on Premier Automobile at B.

It will be observed that the radius for the inner circle is 33$\frac{9}{32}$ inches, while that for the outer arc is 35$\frac{9}{32}$ inches. The length should correspond to the circumference of the clutch cone, or 44$\frac{3}{16}$ inches. The rough or flesh side of the leather is placed outside.

Plate and Disc Clutches.—Multiple disc or three plate clutches are subjected to practically the same main troubles as found in the cone type, i.e., they will engage harshly or fail to transmit the engine power in a positive manner. If a multiple disc clutch of the all-metal plate type does not release properly, it is because the surfaces of the plates have become rough and tend to adhere together. The plates should be smooth and free from any rough particles or score marks, as these will always produce harsh engagement. This condition also results if there is insufficient oil or unsuitable lubricant in those types where the discs are designed to run in an oil bath. "Spinning" or continuous rotation of a multiple disc assembly often results from seizing due to gummed oil; the presence of carbon or burnt oil between the plates, and in some cases by a lack of oil between the members. When an all-metal multiple disc clutch slips, this generally results because of reduced strength in the clutch springs, distortion of the plates, or the use of too heavy lubricating oil. To secure the best results from a multiple disc clutch it is imperative that only certain grades of oil be used. If one uses a cheap or inferior lubricant it will carbonize because of the heat present when the plates slip, or it will gum up owing to the admixture of animal fats or other adulterants.

In a number of cases faulty multiple disc clutch action is due to "brooming," which is a name given for a defective condition that exists when the sides of the kyeway have become indented and prevent free movements of the plates, or when the plate edges become burred over and prevent full contact of the plates. In most cases the adjustment of a multiple disc clutch is easily accomplished by adjusting nuts that may be easily reached if the clutch is of the dry plate type, as shown at Fig. 320, A, which is a representation of the 1914 Hupmobile clutch. The adjusting nut is indicated and there are a number of these carried around the

periphery of the flywheel. Whenever the dry plate clutch is used, one set of the series of discs is faced with some friction material, such as Raybestos, and, of course, when this facing wears it must be replaced with new just the same as advised for the cone clutch. These facings are usually of asbestos fabric, and must be procured woven in the special ring form of suitable dimensions for that specific make of clutch. It is not possible for the repairman or motorist to cut his own plate facing, as the material is hard to handle and there would be much waste if attempt was made to cut it in segments from a wide strip of material.

A typical multiple plate clutch of approved design is shown at Fig. 320, B. This is used on the series X Premier car. It is intended to operate in oil and is housed in a dust-proof casing attached to the rear of the fan-blade-spoked flywheel. Connection between the clutch and gearset is by means of a hardened floating shaft A, broached at its forward end to engage with the clutch, and having at the rear a joint coupling B, which engages with a similar part C on the gearbox. The sleeve B, which carries the coupling slides upon the clutch shaft may be easily moved forward by removing the clamping collar D. This is split so that it may be easily removed from the threaded portion. In removing the clutch the first operation is to displace the floor board in order to gain access to the clutch casing. Remove the cotter pins E from the pins F in the pedal shaft end of the cradle. Remove the split nut D from the clutch shaft A and slip the sleeve B forward, in order to release it from the coupling C. Next remove the eight retaining screws G in the clutch cover on the flywheel, which will permit of removing the clutch and drive shaft. To take the clutch apart back off the clutch nut H, which will release the clutch spring and enable that member to be lifted out. The spring nut H is not used for making adjustment, as none is necessary. A spanner wrench or two quarter-inch pins used in connection with a bar may be employed for backing off the clutch nut H. The clutch cover J can be easily removed by taking out the spring, and the small and large plates L and K will be found on the clutch plate holder.

These plates should be taken off and thoroughly cleaned. If

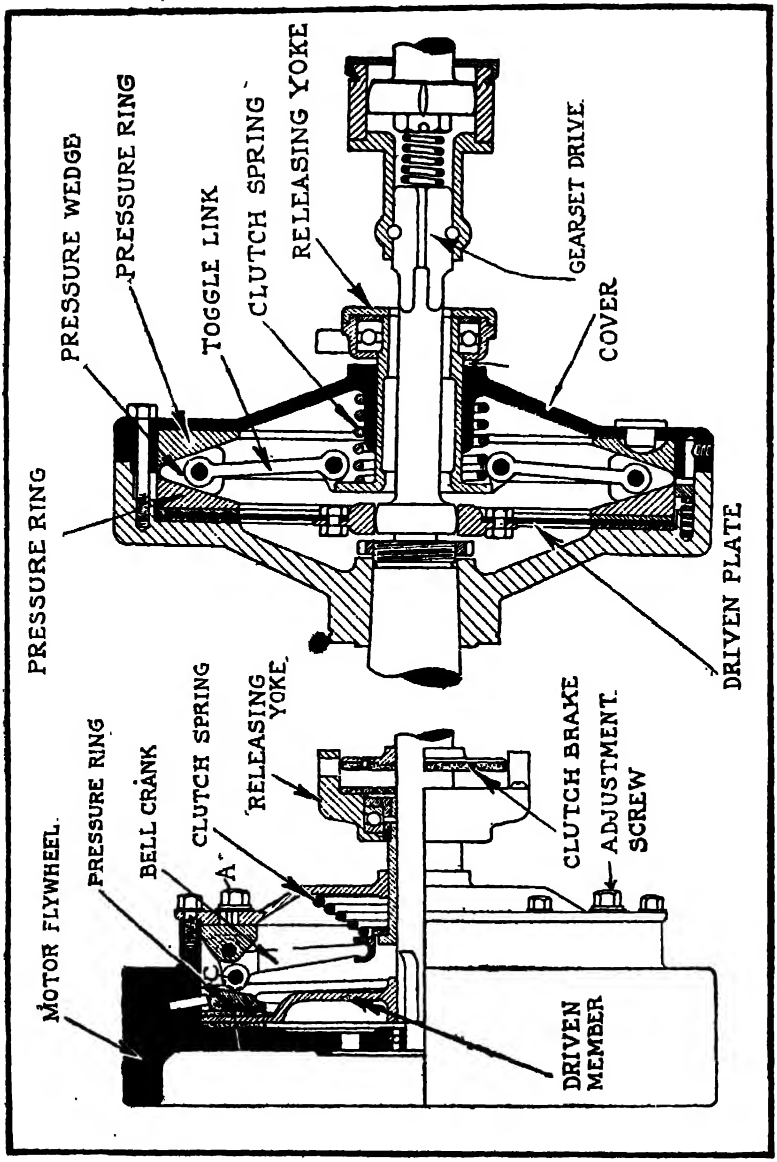


Fig. 321.—Construction of Typical Three Plate Clutches Outlined.

considerable depreciation is noted, new ones should be substituted for the worn members. The small plates L have lugs upon their inner edges which engage in the keyways or grooves cut on the face of the spider. The large plates K have a series of lugs on their outer edges to fit into the grooves in the clutch cover. In reassembling this clutch it is important that the lugs of the large disc are so arranged as to fit alternate slots, thereby providing space between every other plate for the placing of the small springs which must be assembled so as to project toward the rear of the car. The last two springs are arranged to touch the inside of the clutch cover. The object of these small springs N is to force the clutch plates K apart when the clutch pedal is released.

Before replacing the clutch cover, coat the edges with shellac to insure an oil-tight fit. Slide the clutch shaft A forward into the clutch until it strikes the bottom of its socket. Slide the sleeve B with the three joint coupling back until it engages with the coacting member on the transmission primary shaft. Replace the split nut D, screwing it along the shaft until both the shaft and the sleeve are forced securely into place, then screw the nut forward about .03 inch to allow that much end play in the clutch shaft, and tighten the two screws securely. The makers of the Premier clutch recommend lubricating the clutch every five hundred miles. This is accomplished by removing the filler plug and using a funnel to replenish the supply. If the clutch is suspected of chattering or harsh engagement, the first step is to make sure that all the motor cylinders are firing regularly and that it is the clutch that is at fault. If the clutch drags or does not release promptly, inject about a pint of kerosene, running the motor a few minutes with the clutch disengaged and with the gears engaged in the gearset. This holds the clutch spider or disc carrier stationary, whereas the other set of discs, which is carried by the clutch case, revolves and washes the kerosene thoroughly between all the plates. Remove the kerosene after this operation is completed and refill the clutch case with new, clean oil. The clutch operating linkage should be lubricated every day and the grease cups just to the rear of the clutch housing should be turned down frequently.

Examples of the three plate clutch construction in which a

single large driven member is used, faced with rings of friction material, are shown at Fig. 321. That at the left is the Haynes clutch, the spring pressure being multiplied by a bell crank which presses the clutch pressure ring against the driven member and brings that to bear against a suitably machined face on the flywheel web. The driven member is carried by and rotates with the shaft used to transmit the power of the clutch to the gearset. It is possible to compensate for wear of the friction faces by screwing in on the adjustment screws A which push the ring member carrying the bell cranks closer to the pressure ring. Owing to the large size of the driven member this type of clutch will continue to rotate after the clutch spring pressure is released unless a clutch brake is provided. This is a very simple construction consisting of a plate attached to and turning with the shaft supporting the driven member and a friction pad carried by the releasing yoke. The general construction of the clutch is so clearly shown that further description seems unnecessary.

Another form of three plate clutch which is used on some models of the White automobile is shown at the right of Fig. 321. In this the driven plate is clamped between the flywheel face and the pressure ring by a force exerted against a pressure wedge by the toggle links which are pressed outward by the usual form of coil spring. When it is desired to interrupt the drive the releasing yoke is moved so that the clutch spring is compressed and the toggle links pull the pressure wedges from between the inclined faces of the pressure ring. A variety of multiple disc clutches is shown at Fig. 322, all of these operating on practically the same general principles. That shown at A is used on the Chandler automobile. That at B is an all metal disc assembly of Franklin design. The King clutch is shown at C, this having a series of adjusting nuts AAA, which may be used to augment the clutch spring pressure if the clutch shows any signs of slipping. The clutch used on the Hudson cars is shown at D. This also employs a series of small springs having adjusting means instead of one large coil spring not provided with any compensation for loss of strength. The clutches shown at A, C and B have plain metal discs alternating with heavier plates provided with cork inserts. The

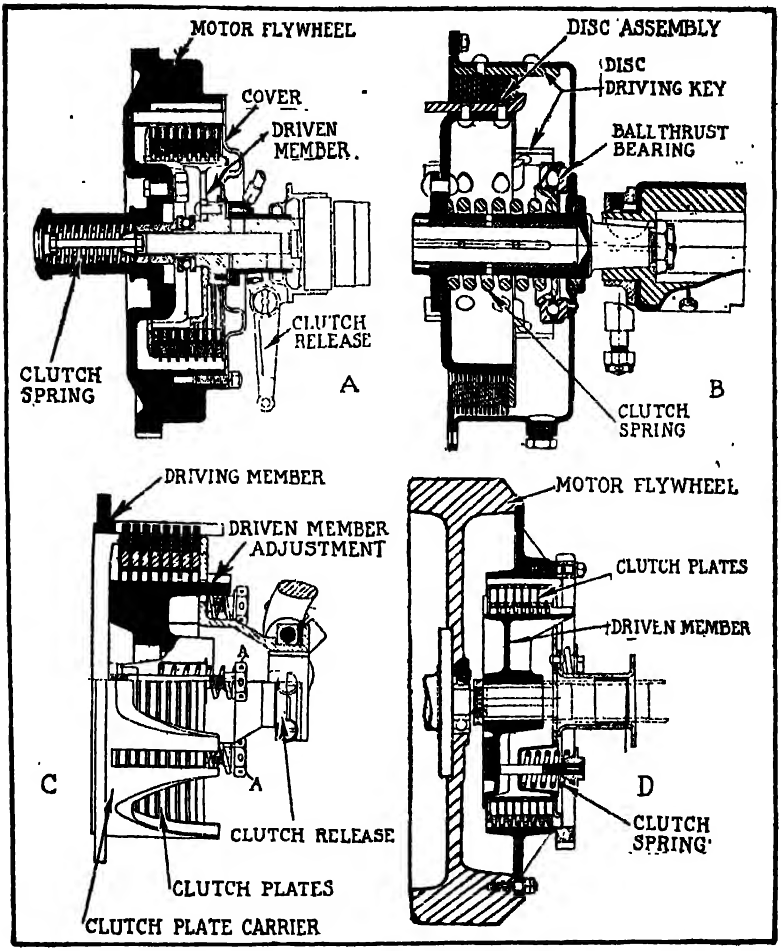


Fig. 322.—Group Showing Multiple-Plate Clutches Used on Modern Automobiles.

same instructions previously given in connection with the other multiple disc clutches apply to these forms as well.

The relation of a multiple plate clutch to the complete power plant and gear box assembly is clearly shown at Fig. 324. The multiple dry plate clutch shown detached from the gearset unit

employed on the 1915 8-cylinder Cadillac is shown at **Fig. 325.** It will be observed that the clutch disc driving member which is bolted to the flywheel has a series of driving keys riveted around its inner periphery. These are to engage the projecting driving members which extend from the outer facing of the plain metal discs. The asbestos friction material faced plates are carried by the clutch spider, the pressure maintaining contact is exerted by a concealed coil spring carried in the interior of the clutch assembly. A plan view of the gearset with the cover plate removed

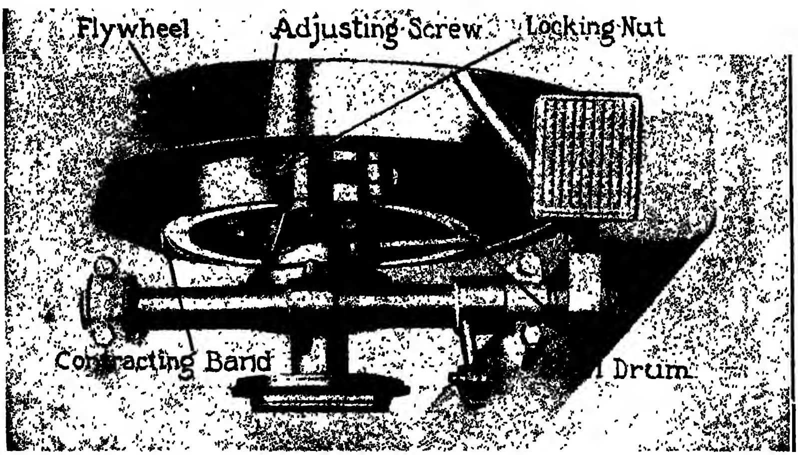


Fig. 323.—External Constricting Band Clutch of Haynes Design.

and showing the mainshaft and the shifting gears is also included in this illustration.

Band Clutches.—Band clutches have been used to a limited extent in automobile construction, though these have never received the wide application that the cone, three plate and multiple disc clutches have. Many early models of Packard and Peerless automobiles used an internal expanding band clutch faced with leather. Means of adjustment was provided by which the degree of expansion relative to the movement of the expanding toggle linkage could be varied to some extent. This adjustment was very sensitive and required expert attention. If the clutch facing became

worn or soaked with oil it was much more apt to slip than a cone clutch, so as soon as the leather facing had worn slightly and the adjustment had reached its limit, it was necessary to reface the band. This was done in the same manner as advised for replacement of worn cone clutch frictions, though more care is needed in truing off the face of the leather.

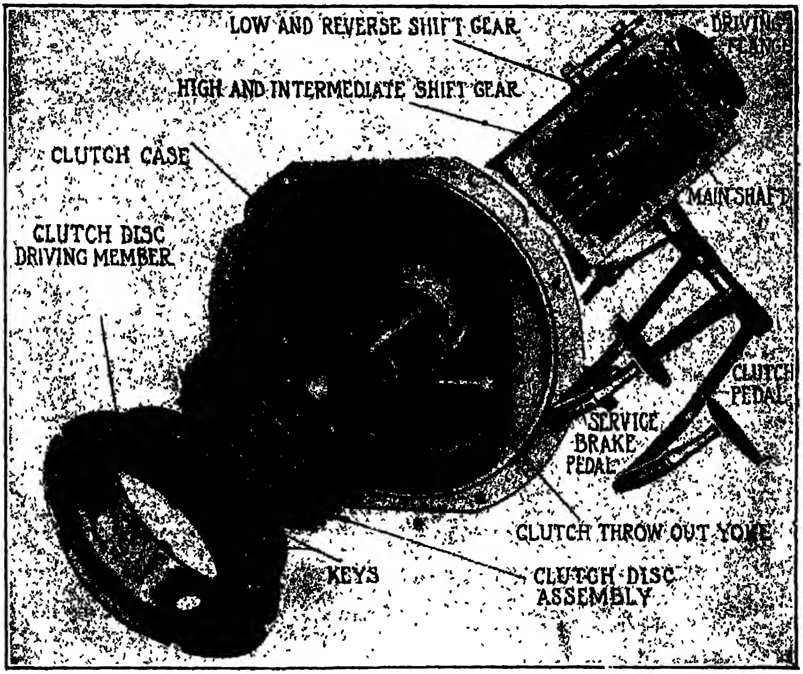


Fig. 325.—Clutch and Gearset of 1915 Cadillac Automobile.

An external contracting band clutch which was used on a number of models of the Haynes cars is shown at Fig. 323. In this a contracting band is tightened around a steel drum attached to the flywheel by a simple leverage, as indicated. An adjusting screw was provided for compensating for wear of the clutch band. In order to adjust the band the locking nut was unscrewed and the adjusting screw set to obtain the required amount of friction band contact.

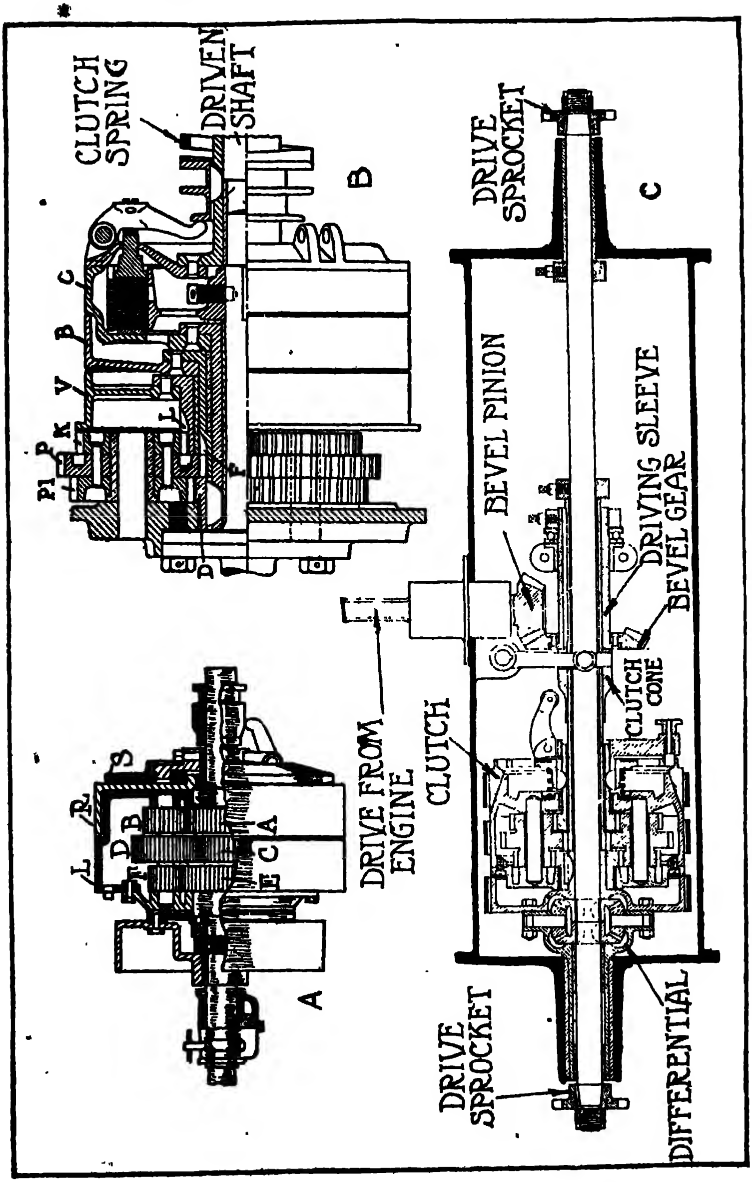


Fig. 326.—Outlining Construction of Modern Planetary Transmission Gearing.

Planetary Gearset Repairs.—The simplest form of geared change speed mechanism is the planetary gearset in its various forms. It is not the simplest in construction, but it is the easiest to control. At the present time planetary gearing is seldom used, as practically all automobiles use the sliding gear type. There are many cars of early design, however, which use this form of gearing, and it is standard equipment on the Ford automobile. Various planetary gear constructions are shown at Fig. 326. That at A is an all spur type, no internal gears, such as were employed on the early forms being utilized. The shafts are divided, the one at the right is geared to the crankshaft and drives the gear C. Gear A is a running fit on the shaft, while gear E is keyed to the shaft at the left, from which the drive is taken. Pinions F, D and B are fastened together on one common shaft, so that they must rotate as a unit at all times. Three sets of these gears are provided, these being spaced equidistantly in the carrying case. To obtain the slow speed ratio a contracting band is clamped around the housing L, and when this is held stationary the drive is from the gear C to the member D, from gear F which turns at the same speed as gear D to the large driving member E which is attached to the driving shaft. Reverse speed is obtained by tightening another band on the drum R. This drum is attached to the gear A so that when the brake is applied at R the gear A must remain stationary. On reverse speed the whole gear carrying housing must rotate about the gear A. From the engine shaft the power is transmitted to gear C, and from thence to gear D. As three pinions are fastened together any power imparted to these produces motion of F and B also. When these three gears rotate, gear E is forced to travel over A, which is stationary, and thus produces rotation of the drum L. From gear D the power is transmitted through gears F and E to the rear. To obtain a high speed or direct drive the clutch member S is forced against the drum R so these two members must rotate together; this locks the entire transmission and causes it to rotate as a unit; as gear A is fastened to the drum R it must also rotate with it and the clutch S. This locks the gears F, B and D in position, and as they cannot rotate they act as a lock for the entire assembly. The driven shaft

at the left, therefore, turns at the same speed and in the same direction as the driving shaft at the right, which is connected to the engine.

The planetary transmission used on the Ford automobile is clearly outlined in part section at Fig. 326, B; the various adjustments and operating pedals are shown at Fig. 327, and a top view showing its location relative to the flywheel of the engine is shown at Fig. 328. The various adjustments are clearly outlined at Fig. 327. The operation is practically the same as the gear shown at A, there being three groups of planetary pinions P-1, P and K. These are riveted together so they must turn at the same speed. Gear P-1 meshes with gear D, which is keyed to a driven member attached to the drum C. The drive gear F is mounted on the end of a bushing which is riveted to the brake drum D. The gear L is attached to the brake drum B. The clutch is a multiple disc type normally held in engagement by a coil spring.

Three brake bands are used for this transmission, the one that constricts around the drum C is the foot brake and acts to retard movement of the car regardless of whether any of the other clutches are engaged. Tightening a band around drum B produces a slow speed. When the band is tightened around the drum V or that nearest the flywheel, a reverse motion is obtained. To apply either the slow speed or reverse band it is necessary to break the direct driving connection by releasing the clutch spring tension and allowing one set of clutch discs to move independently of the other set. One set of the clutch plates is carried by the clutch case C which is keyed to gear D. The other set is carried by a clutch disc carrier which is supported by an extension of the engine crankshaft and prevented from turning by a set screw passing through the clutch disc carrier hub into the shaft. The adjustment of the Ford clutch is a very simple operation, this consisting of releasing the set screws in the clutch fingers by pulling out the split pin that acts as a lock and turning in the adjusting screws. The slow speed adjustment is at the side of the gear case, and may be reached without removing the cover plate of the transmission which is necessary to adjust either the reverse clutch band or the foot brake band.

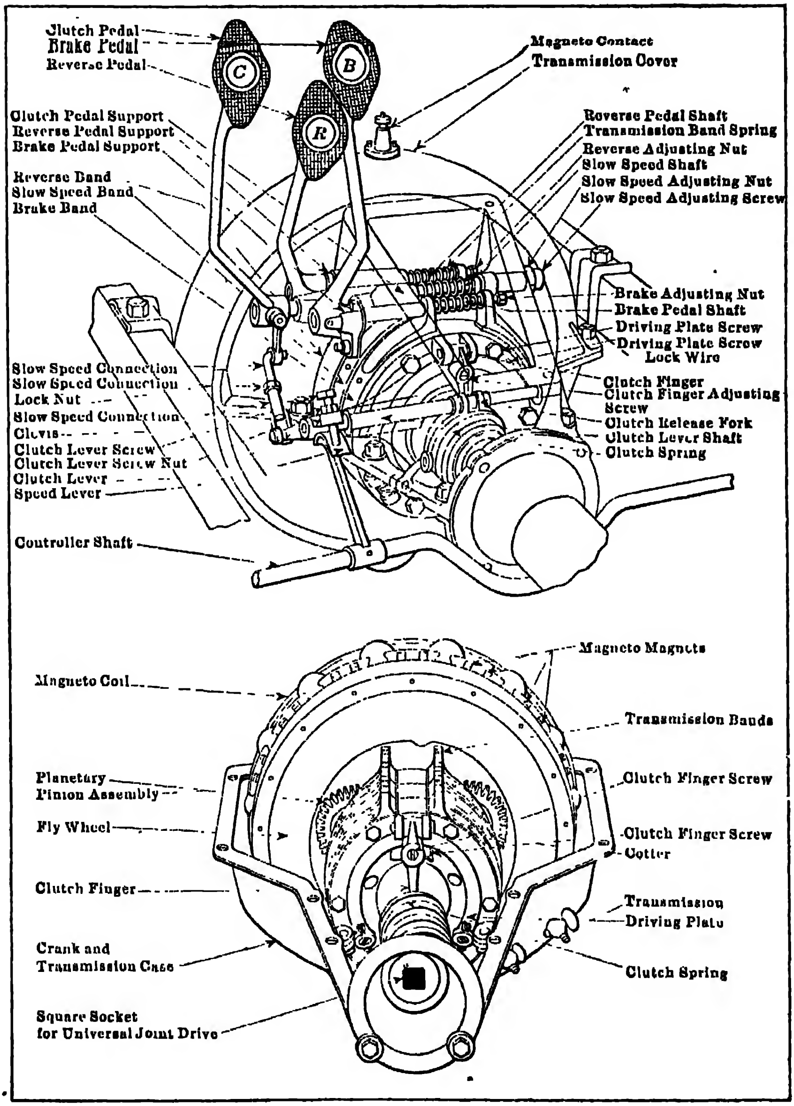


Fig. 327.—Illustrations Showing Method of Adjusting Clutch Bands of Ford Planetary Transmission.

Another planetary transmission which is incorporated with the jack shaft unit is shown at Fig. 326, C. This is used on the Koehler truck. In operation it is the same as that shown at A, as three brake bands are provided, one acting as a foot brake while the other two provide the reverse and slow speed ratios, respectively. The contracting band on the transmission serves as a service brake. The entire jackshaft unit including bevel driving gears which derive their power from the engine, the differential and brake bands are enclosed in a cylindrical housing extending across the frame which is lubricated by oil splash. The counter-shaft revolves on long main bearings. When it is desired to adjust the high speed clutch of the transmissions shown at A and C it is necessary to release the locking means and screw the spider member carrying the clutch fingers in closer to the drum R in the transmission shown at A, while in the Koehler design a simple spring pressed plunger lock is provided. When it is desired to tighten the clutch this plunger may be withdrawn and the finger carrying spider screwed around as much as necessary. After the adjustment is secured it is locked securely by dropping the plunger in one of the holes made to receive it on the clutch female member.

The chief trouble with a planetary transmission results from slipping clutch bands. In all cases these are provided with adjustments that can be tightened in event of wear of the friction linings up to a certain point. When the friction material wears thin, new brake lining must be riveted to the clutch bands. Care must be taken when making adjustments not to tighten any of the bands too much, as if these bind on the drum they will produce friction which results in heating and wearing away of the brake lining and will also decrease the efficiency of power transmission. Noisy action of a planetary transmission is usually caused by excessive wear in the gearing. Slipping of the high speed clutch may be easily remedied by making compensation for wear by the methods of adjustment previously described. When taking down a planetary transmission it is important to note the condition of the bushings on which the planetary pinion groups rotate. If these are worn or if the pins supporting them become reduced in size, the gears will rattle when in use and the transmission will

be noisy on low and reverse speeds and when in neutral position, though it will be silent in action on the high speed.

The brake drum surfaces often become grooved, and these may be deep enough as to seriously reduce the strength of the

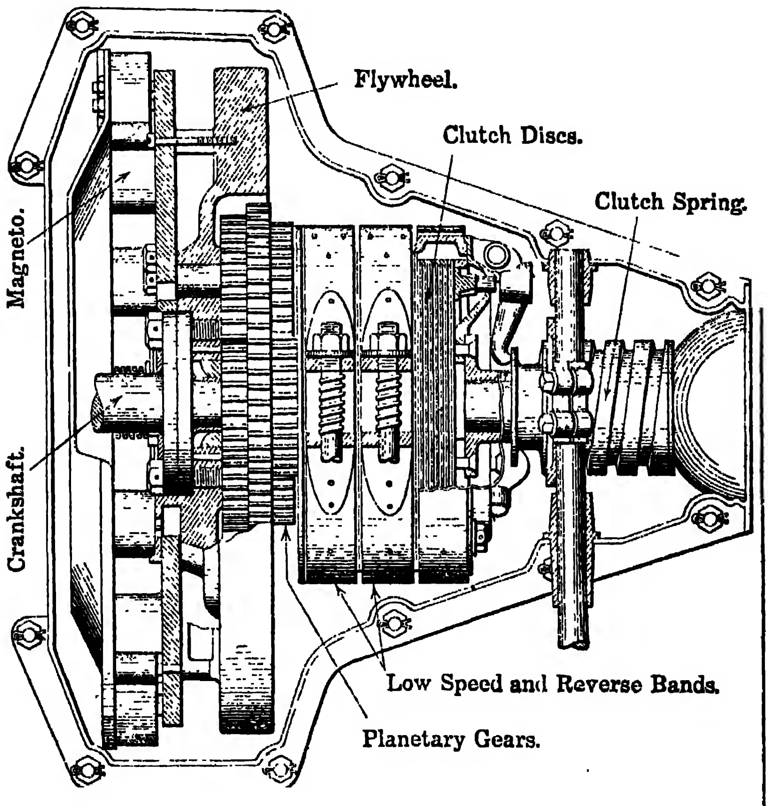


Fig. 328.—Top View of Two Speed and Reverse Planetary Gear Employed on Ford Cars.

brake drum. Where this condition is noted new brake drums must be provided, though in some cases where the brake drum forms part of the gear containing case, as in the transmission shown at A, it may be possible to turn down the surface enough so that a

ring of cast iron or steel may be shrunk around the worn drum and securely retained to that member by pinning. It is also possible to fill in very deep grooves with cast iron melted in with the oxy-acetylene torch and then machining off the surplus material in a lathe or grinder to bring the drum to proper contour. As the gears are always in mesh in a planetary transmission the teeth of these members are not likely to wear much, practically all the de-

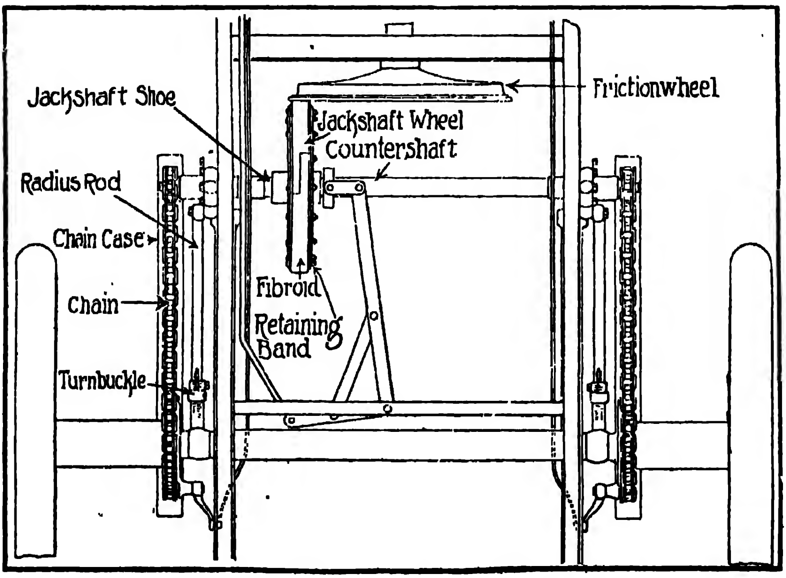


Fig. 329.—Metz Friction Disc Transmission.

preciation existing on the planetary gear supporting bushings and pins. In some planetary transmissions the brake drum bushings are short and apt to wear. This also produces noisy action and these bushings must be replaced with new ones when worn. Care must be taken that all retaining keys and pins are not worn and that casing retaining screws are screwed up tightly. The instructions given for multiple disc clutches in the beginning of this chapter apply just as well to the clutches used in planetary transmission when these run in an oil bath.

Friction Drive Faults and Remedies.—Many cars have been sold throughout the country, but more particularly in the Middle West, equipped with friction or rolling traction transmissions of various types. The simplest form, and the one most widely adopted by automobile manufacturers, consists of two discs, one driven by the engine, the other attached to a cross shaft in such a manner that it can be moved across the face of the engine driven member to give the various speed ratios. The movable disc consists of a flanged cast iron wheel that is faced with a ring of compressed strawboard or other fibrous material, that driven by the engine is generally faced with an aluminum-copper alloy, as this combination has been found to give the best results and transmit power without excessive pressure to maintain the parts in frictional contact. These drives have not been discussed in trade prints or books as much as the geared forms, as it is evidently assumed that their simplicity makes them easy to understand and maintain. While there is very little to get out of order or cause trouble, it is possible that difficulty may be experienced in transmitting power and the mechanism condemned because one does not know where to look for trouble.

The common trouble is failure to drive properly, and this may be produced by a number of distinct conditions. It may result from accumulations of oil on the frictional surfaces, which reduce the amount of frictional adhesion, "brooming" of the fibrous material, wear at the face of the aluminum member, spring or lost motion in the countershaft or lost motion at the various members of the pressure linkage that would prevent positive contact of the friction elements. If the bearings supporting either the cross or main shaft are defective, or the thrust bearing to which the pedal pressure is applied works stiffly, the increased friction at these points will cause serious diminution of power. In case slipping is noted, the first point to examine is the contact surfaces and make sure that there is no excess of oil between them. If oil deposits are seen, they may be removed with gasoline and the surface of the aluminum plate dusted over with talc or Fuller's earth. If the metal surface of the driving member is scored, grooved or roughened, it should be restored to a smooth surface by refacing.

It is possible to do this with a scraper without removing the driving disc from its shaft and turning it with the engine if care is used in manipulating the tool. The disc should be turned at high speed, and after the surface is smoothed to a certain extent so that the grooves are nearly eliminated, it can be surfaced by moderately fine emery cloth held in a suitable wooden holder and moved across the surface by hand. If the grooves are very deep,

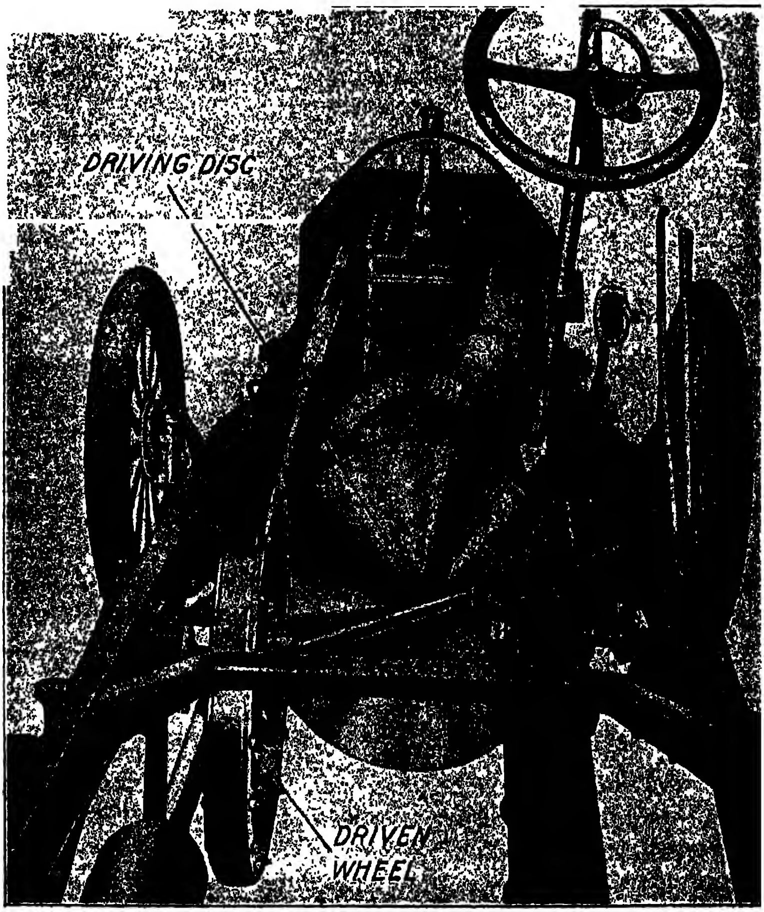


Fig. 330.—The Cartercar Friction Disc Transmission.

it may be necessary to resurface the member in a lathe by taking a light chip off the face with a cutting tool.

The paper friction ring on the driven wheel flattens out with use and does not last long if the pressure applied to keep the members in contact is unduly high and the surface will become roughened as well. It is customary to renew the paper ring at intervals corresponding to about 2,000 to 3,000 miles average road use. If any tendency is noted for the driven member to crowd toward either the edge or center of the aluminum driving disc it can be attributed to wear in the countershaft or main shaft bearings that permits either member to sag, and then the line of contact does not come at the center of the discs which is necessary to secure proper transmission of power. Any condition that will prevent positive or true contact of the friction members will cause slipping. This means that bearings must be properly maintained and that all lost motion in the operating rods or pressure levers must be minimized. The countershaft should be very heavy and not liable to spring or give when the surfaces are brought together, and the frame member supporting the driving plate must be well braced with strong gussets to prevent distortion when pressure is applied at the contact surfaces to maintain friction adhesion.

Two typical friction transmissions which are similar in principle of action are shown in accompanying illustrations. That at Fig. 329 is a representation of the friction drive of the Metz automobile. The view at Fig. 330 shows the arrangement of the parts of the Carter car friction drive. The following instructions pertaining to replacing the fibre when worn applies just as well to both drives illustrated. One of the good qualities of the friction drive is the ease with which adjustments and replacements are made. The jack shaft wheel or driven member carries what is termed a "fibroid" in the Metz car, which is made in two sections to make for easy displacement as well as renewal. It is retained by a locking band secured by bolts as outlined in the sketch. For a period of time wear of the fibre rings is automatically taken up, but after considerable service and when it has become so worn that the clutch pedal must be pushed to its maximum position, a new adjustment must be effected in the distance between the friction

wheel and the driven member. This is obtained by adjusting the nuts on the clutch pedal and the drive plate bracket rods and with the clutch pedal released. To replace a worn fibroid with a new one the bolts are removed and the retaining band is pulled off of the driven wheel. The worn ring is removed in two pieces and the halves of the new member are placed on the rim and the ring or retaining band is again secured to the wheel by the bolt. The parts come all drilled and no difficulty will be experienced in replacing the new fibre friction correctly.

Trouble in Sliding Gear Transmission.—When sliding gear transmissions are employed the most common symptoms of derangement are noisy operation and trouble in shifting gears. The difficulty met with in gear shifting, providing the trouble is not caused by a clutch that does not release promptly, is usually caused by failure of the edges of the teeth of the shifting members, and when these have burred over they will not pass readily into the spaces between the teeth of the gears they engage with. Another cause of poor gear shifting is depreciation of the bearings, especially in those types of transmissions using plain bushings. Any wear or looseness that may change the center distances of the shaft to a certain degree will result in poor meshing because the relation of the gear centers is so changed that the pitch circles will not coincide and the tooth of the entering gear may bottom on the side of the gear with which it should mesh. Noisy operation when not due to mechanical depreciation is usually caused by a defective condition of lubrication. If the gears are not worn too much noise may be minimized to a large extent by filling the transmission case with oil of sufficient consistency to cushion the gear teeth, and yet not be so heavy bodied that it will not flow readily to all bearings Difficulty in shifting is sometimes due to binding in the control levers or selective rods, and all points of the gear shifting mechanism should work freely if prompt gear shifting is required.

If considerable difficulty is experienced in meshing the gears and the trouble is not found in the gearset, it will be well to examine the clutch to see that the driven member furnishing power to the gearset primary shaft does not "spin" or continue to revolve after the foot pedal is depressed. It might be stated in this con-

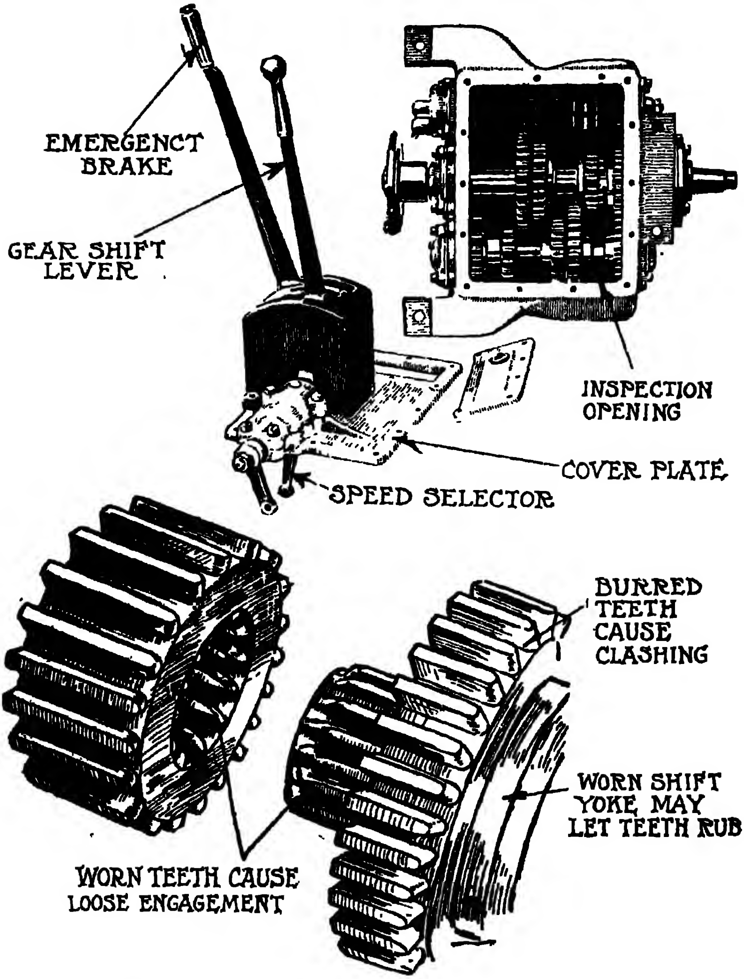


Fig. 331.—View of Jeffery Transmission with Cover Plate Removed at Top, Common Causes of Poor Gear Shifting Outlined in Lower Illustration.

nection that on most of the modern cars having clutches of such construction that spinning may result, clutch brakes are provided. As these are used constantly the friction pad, which is often a

limited area, may wear, in which case renewal is necessary to restore the clutch to efficiency.

Fortunately, most gear boxes are built in such a way that the interior may be readily examined. An example of a large opening provided in a gear box by removing a cover plate is shown at the top of Fig. 331. This is the gearset used on the Jeffery four-cylinder cars. The construction of the various gears as well as the selective members is clearly shown. The control levers are attached to the transmission cover plate, as indicated, but may be readily removed with the cover by taking out the bolts holding that member in place and uncoupling the emergency brake actuating rod. The speed selector, which is actuated by the gear shift lever, fits into suitable depressions in the sliding gear shift rod.

In some transmissions of the sliding gear type the high speed or direct drive is obtained by the sliding gear which provides the intermediate speed having a suitable extension from its face designed to mesh with an internal gear and thus form a positive driving clutch to couple the gearset main shaft portions together. When the teeth on the male clutch member become worn considerable trouble will be experienced in securing positive engagement, and if the wear is such that the width of the teeth is materially reduced a new member will be needed. If the teeth are not worn; but are only burred over at the edges, they may be dressed to proper contour by using a very small, high speed emery wheel on the end of a flexible shaft or by removing the offending member and grinding it in any suitable machine.

Some garage mechanics will anneal a gear in order to soften it sufficiently so that the rough piece may be smoothed with a file. Attempts are afterward made to harden the gear and seldom do these result successfully. In modern gear boxes chrome and nickel alloy steels are used which demand careful heat treatment in order to secure the best quality of steel. These have been carefully developed by scientific laboratory tests and heat treatments are seldom duplicated with the equipment available in the ordinary repair shop. The repairman should not anneal gears unless he is confident that he can treat them properly in rehardening. This means that the nature of the stock as regards its chemical com-

position must be known and that the best quenching point for that particular alloy must also be determined. The use of a small, high speed emery wheel will make it possible for the mechanic to dress the gear without softening it or altering its nature, as an emery wheel will cut hardened steel very easily.

Whenever an old gear is removed and is to be replaced by a new one, it is well to make a rough sketch of the gear you desire, indicating the number of teeth, the pitch, the width, the diameter of the gear and the size of the hole going through it. This insures the receipt of a gear that will fit the defective gearbox, and not one for a later or earlier model car of the same make as that worked on. When the cover is off of the gearbox, as shown at the top of Fig. 331, it is possible to test the amount of wear between the shifting yokes and the portion of the sliding gear members on which they fit. On some selective gearsets there is not much space allowed between the gear teeth, and if the shifting yoke wears it may be possible for the shifting gears to rub against one of the fixed gears on the counter shaft and produce noise. The main and countershaft bearings may also be inspected and tested for looseness by grasping the shaft firmly and attempting to move them up and down or from side to side.

If the various components of the gearset are found defective the gear box must be taken apart and given a thorough overhauling. The means of accomplishing this depends entirely upon the design of the change-speed gearing. In those cars where the gearset is mounted under the floor boards as a separate unit, the entire gearbox may be removed without disturbing the power plant or clutch assembly. Gearboxes of this form are usually of the horizontally divided type, and when the top half of the gearbox is removed the various gears and shafts, as well as speed selecting members, are exposed as shown at Fig. 332, A. The first step is to remove the shifting members which are shown shaded at A, this leaving the main shaft and countershaft in place as shown at B. The next operation is to lift the main shaft out, which leaves the gear box as shown at C. After the primary shaft is removed only the countershaft assembly and the reverse stud gear are left in mesh, as shown at D. Lifting the countershaft out leaves only the bottom

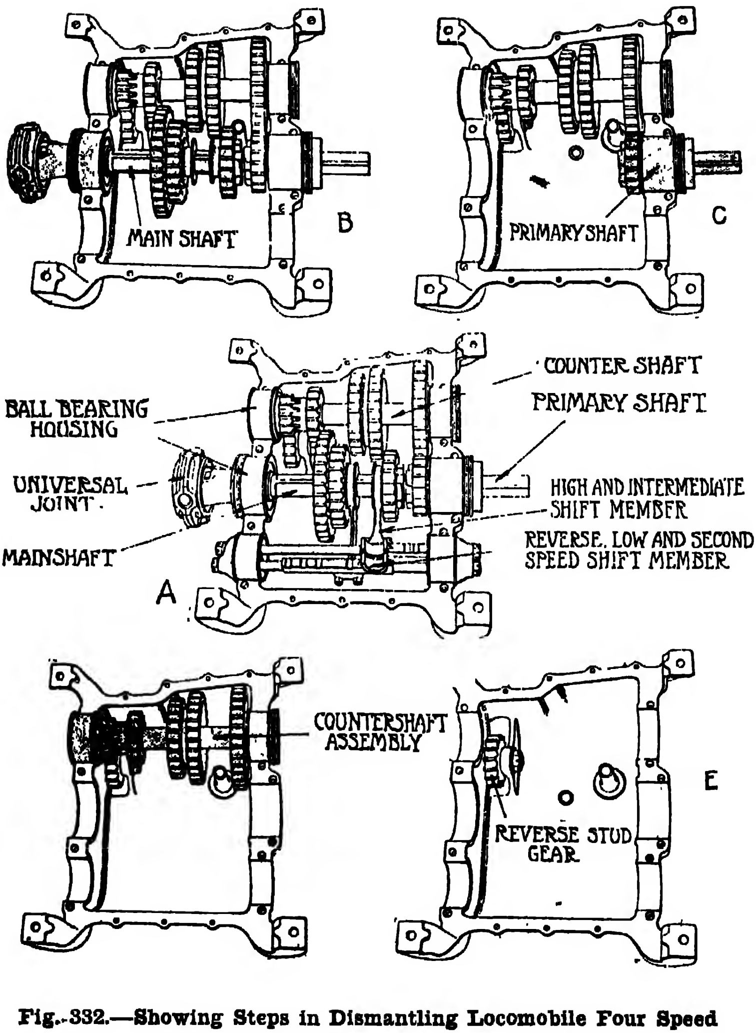


Fig. 332.—Showing Steps in Dismantling Locomobile Four Speed Transmission.

half of the gearset with the reverse stud gear in place, as indicated at E. To reassemble the gearset the reverse process to taking it apart is followed. First the countershaft assembly, which includes

the gears, the shaft to which they are keyed, and the supporting bearings and their housing, is replaced in position. Next the primary shaft member is put in, then the main shaft, and lastly the control members or shifting rods, until the gearbox is again as shown at A, and ready for bolting the top part in place.

The bearings used on the ends of the countershaft are often of the ball form, as shown at Fig. 333. Different methods of re-

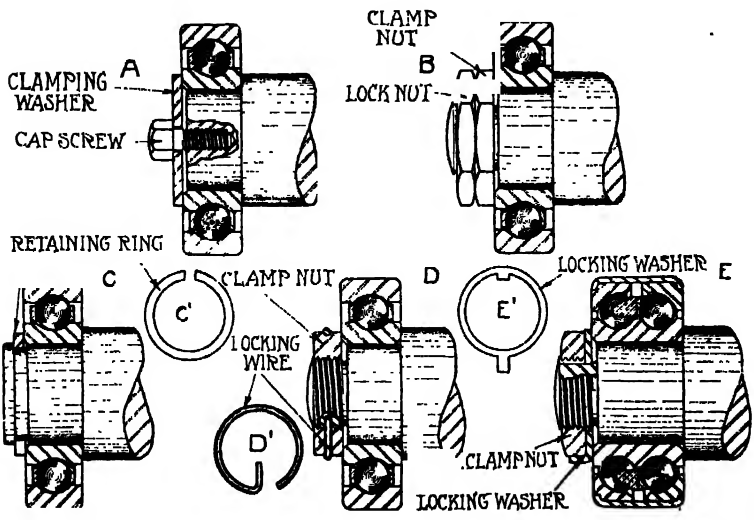


Fig. 333.—Conventional Methods of Retaining Ball Bearing Inner Races on Sliding Gearset Countershaft.

taining the bearing in place are followed. That at A shows the use of a cap screw and clamping washer. At B a clamp nut is used to press the bearing inner race firmly against the shoulder on the shaft, while a lock nut keeps the clamp nut in place. A very simple method, and one that is entirely satisfactory, is shown at C. This consists of grooving the end of the shaft circumferentially and putting in a split ring, as shown at C. A common method of retaining the bearing inner race, and one recommended by ball bearing manufacturers, is shown at D. After the clamp nut is brought tightly against the face of the inner race a locking

wire is sprung around the nut and the point entered into a suitable drill hole which goes through the nut into the shaft as indicated. Another method having much in its favor is shown at E. In this a double row ball bearing is pressed against the shoulder by a

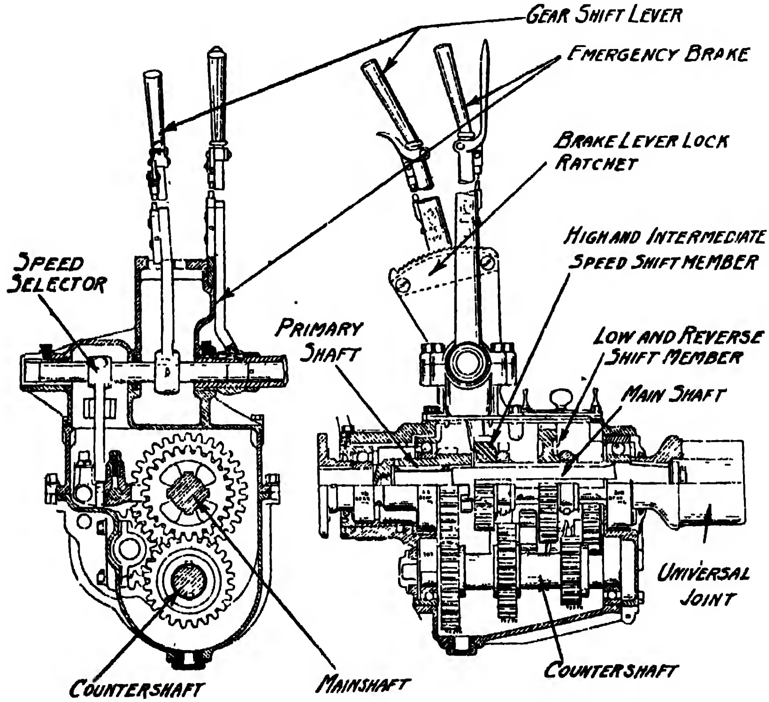


Fig. 334.—Diagram Showing Construction of National Three Speed Sliding Gearset.

clamping nut which is separated from the bearing inner face by a locking washer of the form shown at E′. This has one projection on its inner periphery designed to engage a keyway cut in the shaft. The projection on the outer periphery is intended to be bent around one of the facets of the nut to hold it in place after it has been firmly seated against the locking washer and bearing inner race. Complete instructions for the maintenance and instal-

lation of ball bearings and other anti-friction forms will be found in Chapter IX., which deals with rear axle construction.

The construction of a typical three speed forward and reverse selective transmission showing ball bearings and gear shift members is clearly shown at Fig. 334. This has the gear shaft and emergency brake levers carried by a suitable supporting casting forming part

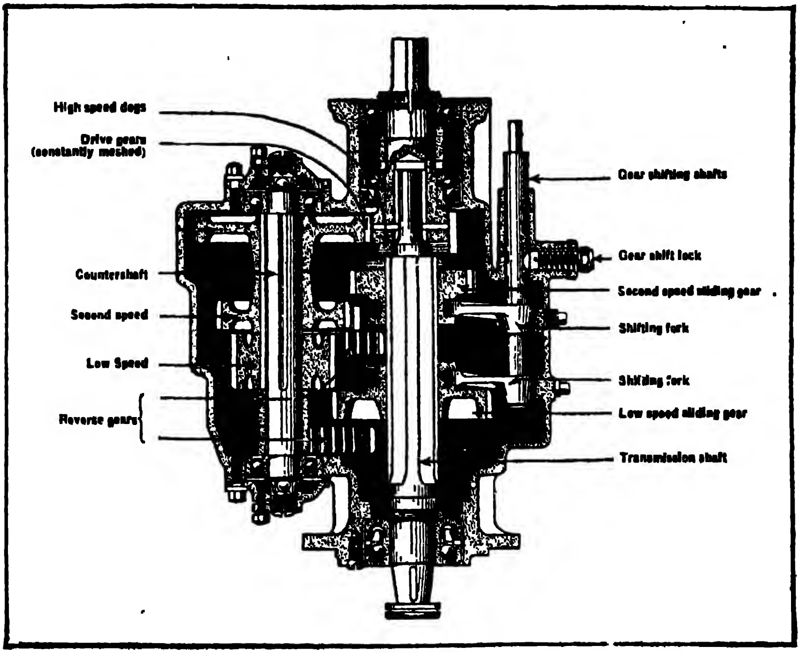


Fig. 335.—Three Speed Sliding Gearset, Forming Part of Rear Construction of Overland Automobiles.

of the gear case cover. In this gear box single row ball bearings are used at all points, except to support the telescoping end of the main shaft, which fits into the primary shaft and which rotates on a roller bearing. The primary shaft is supported by two single row bearings, the outer one being clamped so it holds the shaft steady while the inner and larger one has a floating outer race. When a ball bearing is clamped on both inner and outer races it

will take end thrust as well as radial load. A thrust is usually an endwise load, while a radial stress is a load applied from an up-and-down direction or sidewise. In this gearset the bearing inner races on the countershaft are pushed on tightly, these being a force fit on the shaft ends. No retention means are provided. The general construction of this gear box, which is that used on National cars, is so clearly shown that further description is unnecessary.

A three speed and reverse sliding gear set that forms part of the rear construction on Overland cars is clearly shown at Fig.

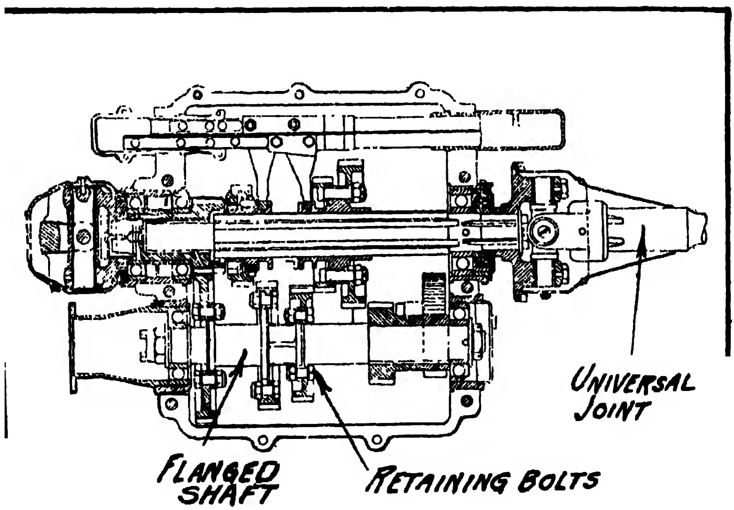


Fig. 336.—Four Speed Selective Sliding Gearset of Approved Design.

335. In this the primary shaft is carried on single and double row ball bearings, while the end of the main shaft to which the bevel driving pinion is secured is supported by a large double row bearing which is capable of taking end thrust and radial load in combination. The single row bearings on the end of the countershaft are subjected to radial loads only as the countershaft is kept from end movement by simple thrust members composed of a steel ball fitting into an adjustable screw plug. The gear shifting forks

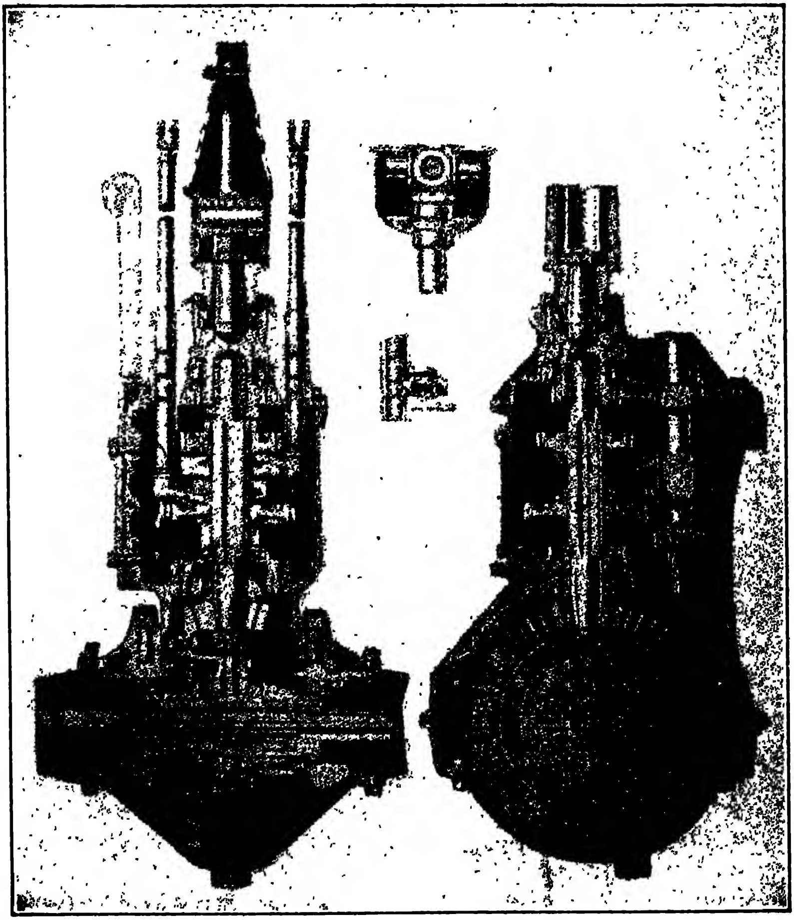


Fig. 337.—Showing Application of Three Speed Sliding Gearset to Studebaker Rear Axle.

are attached to the gear shifting shafts by means of taper pins which may be driven out to release the forks and permit of taking the transmission apart by removing pipe plugs in the side of the gear case which gives access to the retaining pins when the sliding gear members are in the neutral position as indicated.

In some gear boxes, especially those used on high-priced auto-

mobiles, the gears are in the form of rings which may be bolted to the shifting members and to flanges on the countershaft as shown at Fig. 336. The point advanced in favor of this construction is that it is possible to renew only the defective toothed ring instead of replacing an entire shifting member as is necessary when the gears and hubs are formed integrally. It is also contended that the use of bolts to hold the gears firmly against flanges machined integrally with the countershaft makes for more secure attachment than the cheaper method of keying. The gear box design shown is used only on high-powered cars, where secure means of retaining the gears are absolutely necessary. A gear box of this design is very costly to manufacture, but it is cheaper to keep it in repair than the simpler forms.

The change speed gearing is often combined on the rear axle, as shown at Fig. 337. This outlines a top sectional view through the rear construction and a side sectional view showing the disposition of parts very clearly. It will be observed that the bevel pinion carried on the back of the main shaft drives the bevel ring gear attached to the differential housing directly. As the gear box is part of the rear construction it is possible to secure exact alignment between the driving gears, and no power is lost due to faulty alignment between these members as may sometimes occur when the gear box and rear axle are separate components and the frame is distorted due to rough roads.

A four speed gear box having clutch integral, a somewhat uncommon construction, is shown at Fig. 338. This design is used on some models of the Winton automobile. Three shifting yokes are used, shift member A controlling the direct drive, which in this case is a third speed, and the second speed. Shift member B gives the first or lowest forward speed and the reverse ratio. Shift member C is used to engage the fourth speed, which is a high ratio obtained through speeding up gears instead of reduction gears. With gear sets of this character all normal driving is intended to be done on the third speed or direct drive. The geared-up fourth speed is called upon only when conditions are favorable and high vehicle speed is desired. This gearset is a form in which but little clearance obtains between the shifting members and the non-shift-

ing gears, and is a form where depreciation of the shifting yokes may result in the gears grating even when in neutral position.

In those forms of gear boxes where the ends of the shafts are supported by single row ball bearings with no special provision for end thrust, noisy action may result in a very short time due to misalignment of the ball bearings at the end of the shaft. Whenever the shifting members are moved to change a gear a pressure of from 75 to 100 pounds is exerted through the shifting yokes on

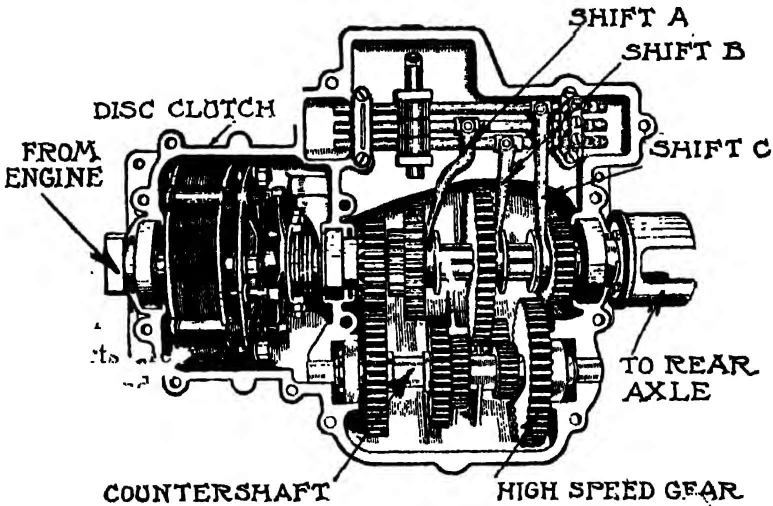


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Fig. 338.—The Winton Four Speed Sliding Gearset, Having G... High Speed, and with Clutch Carried in Gear Case Exte... joints ...he car

the sliding gear members, and if these do not engage ...g some
this pressure becomes an end thrust in the ball bearing. control
when these are new and practically unused that this p...ose cross
be resisted without pushing one of the ball races a t...p in ser-
line with the other. As soon as the wear in a radial b... between
amounts to a few thousandths of an inch, which doe... nections,
ciably affect the radial capacity of the bearing, the b...ness of the
to end thrust or lateral pressure to a certain exten...hat will be
wise movement of the shaft results whenever an ...apter.

applied due to poor engagement of the shifting gears. It is not only the pressure from the gear lever that must be taken into account, but the endwise shocks received in changing from a lower to a high gear also assist in producing depreciation at the bearing. The theoretically correct parallelism of the main and counter shaft is eventually lost if a suitable allowance in the dimensions of the different ball bearings does not serve to equalize the wear due to radial load in the ball bearings at both ends of each shaft. As the gear tooth pressure is highest at the ends where it is transmitted with a large speed reduction to the low gear, this point applies specially to commercial vehicles in which the low gear is used more than in pleasure car service.

Where the use of special end thrust bearings is considered too expensive, adjustable hardened end thrust-sustaining members, such as shown at Figs. 335 and 338, may be used at the ends of the countershaft. Owing to the lack of solidity of aluminum gear box castings, it is usually the plan in constructions of good design, such as at Figs. 332, 334 and 336, to mount the bearings in flange steel or bronze housings in order to enlarge the areas over which the bearing pressures are transmitted to the soft aluminum. Noisy gear box action is sometimes produced due to thin [illegible] walls which possess sound magnifying qualities, and this fea[illegible] one may multiply the volume of noise that would normally be caused by the gear action three or four times, especially if the bearings are [illegible]ted in such a way as to set the gear box in vibration when worn. [illegible]ay noise can be reduced is by keeping the ball bearings [illegible]ndition and filling the gearset with a viscous lubricant, [illegible]e mineral grease, which will provide a cushioning effect [illegible] vibration produced by roughness in either gears or

CHAPTER VIII

FAULTS IN CHASSIS COMPONENTS

Chassis Types—Dismantling a Chassis—Straightening a Bent Frame—Trussing a Weak Frame—Repairing Cracked Side Member—Care and Repair of Springs and Spring Parts—Compensating for Steering Gear Deterioration—Drag Link and Tie-Bar Repairs—Testing Wheel Alignment—Radius Rods, Torque Members and Control Linkage—Universal Joint Forms and Troubles—Front Wheel Adjustment—Muffler Faults—Chassis Lubrication—Locating Acetylene Gas Leak.

EVEN after the power plant and gearset have received attention, there are numerous points about the chassis of the car that should be inspected if a thorough overhauling is called for. The chassis of any well built car will need but very little attention if the various parts are well oiled until it has been used from ten to fifteen thousand miles. After this distance has been covered, the motorists will probably be annoyed by a series of squeaks and rattles, even though the engine and gearset are in perfect running condition. These rattling noises indicate wear at a number of relatively unimportant bearing points, and even though the depreciation is slight, the looseness at the multiplicity of small joints will produce a noise that will be unmistakable whenever the car is operated on other than perfectly smooth highways. Among some of the things to be looked for are wear in the various control linkage members, sagging or bent frame side members, loose cross members or gusset plates, due to rivets having loosened up in service; stiff action of the springs, due to rust accumulating between the leaves; looseness in the steering gear and steering connections, lack of alignment of the front and rear wheels, looseness of the wheel hub bearings, and numerous other conditions that will be enumerated and discussed in this and the following chapter.

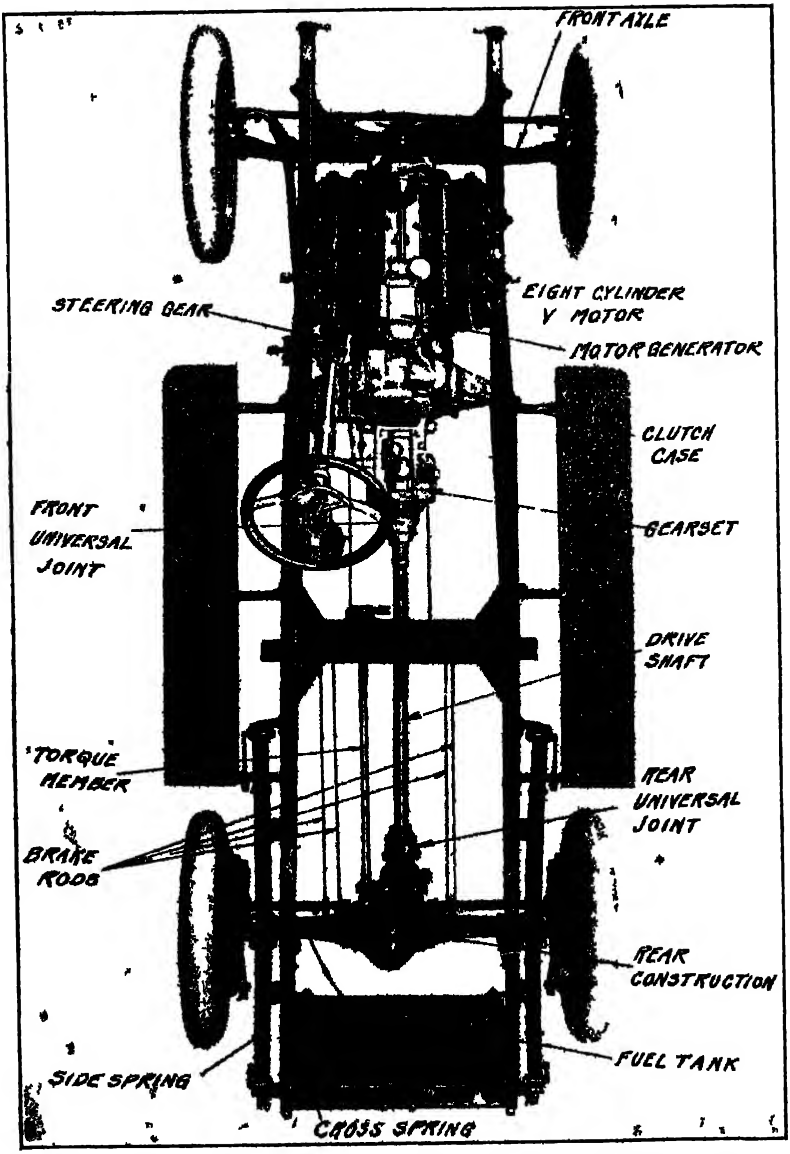


Fig. 340.—Plan View of the Cadillac 1915 Chassis, Showing Location of Eight Cylinder V Motor and Unit Gear Set

Chassis Types.—Before discussing the points to be inspected and the manner of making repairs when defects are found, it may be well to describe briefly some of the typical chassis constructions in order that the novice repairman may get an idea of the relation of the parts in cars of conventional design. The side and plan views of a National four-cylinder chassis are shown at Fig. 339, all the important components being clearly indicated. This may be considered a good example of high grade car construction in which the power plant and change speed gearing are separate units. As is apparent, the engine may be removed from the frame without disturbing the change speed gearset while the gear box may be taken out without requiring the removal of the engine. The general construction of this chassis is conventional and follows established automobile engineering practice. It has the virtue of having the parts readily accessible so that repairs may be easily made without disturbing other components except those that are to be worked upon.

The plan view at Fig. 340 shows a chassis of recent development produced by the Cadillac Company which is provided with an eight-cylinder V engine having the transmission gearing incorporated as a unit with the engine crankcase. This construction is more accessible than the usual unit power plant is, owing to the design which permits of removing the transmission case from the engine base without disturbing the power plant. In all other respects this chassis follows conventional practice. The important parts are clearly shown and no difficulty should be experienced in identifying them on the actual chassis.

The repairman will be more often called upon to repair motor trucks in the future than he has been in the past on account of the increasing popularity of the heavy duty vehicle. The chassis construction in the main follows the design established in pleasure car practice, excepting for the use of much stronger parts and a tendency to use standard structural steel shapes for frames instead of the special pressed steel side members commonly found in pleasure car service. The average truck chassis will have a pronounced overhang over the front and rear axles in order to obtain a body of sufficient size without unduly increasing the wheel base. Gear

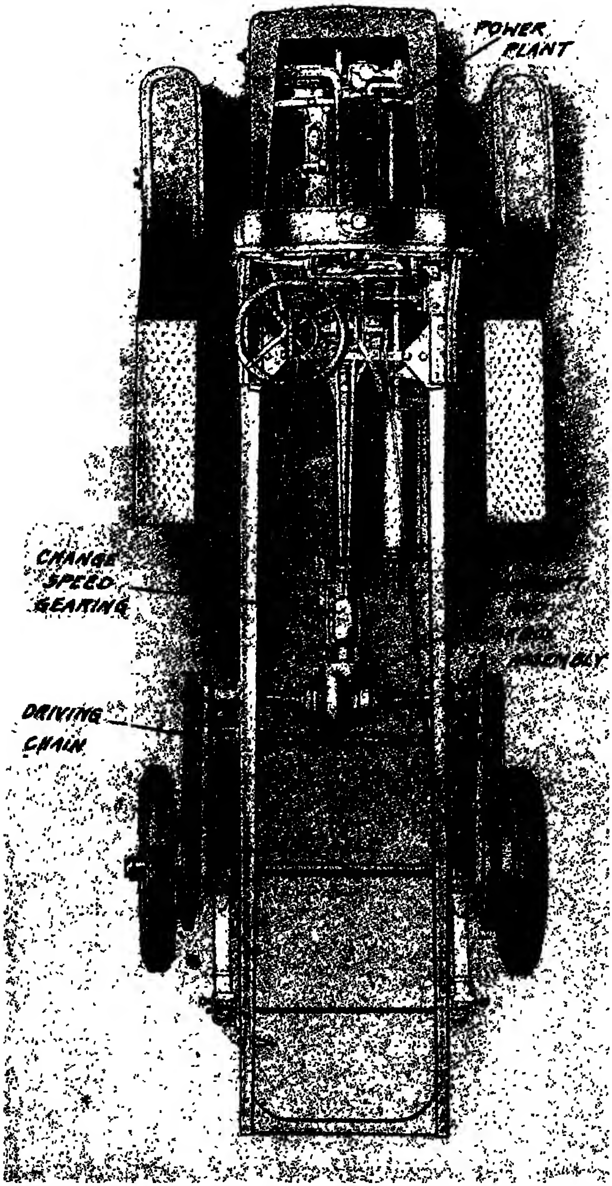


Fig. 342.—Plan View of Typical Chain Driven Motor Truck Chassis.

driven trucks do not differ materially in construction as far as relation of parts is concerned from pleasure cars of the present-day type. The worm drive and double reduction axles are rapidly gaining favor and the conventional side chain drive construction to which most of the trucks have been built is gradually being displaced by the more modern forms having a live axle instead of the fixed non-rotating member shown at Fig. 342. It will be remembered by those who have had automobile experience, dating a number of years back, that many of the powerful pleasure cars were fitted with side chain driving systems. The power transmission was to a jack shaft which was practically a live rear axle having sprockets at the axle ends instead of wheels, and from that member to the rear wheels, which were revolved on a nonrotatable axle by means of driving chains. The process of taking down a motor truck chassis and the points to inspect for depreciation would not differ materially from that used in repairing a pleasure car assembly. Owing to the use of solid rubber tires, a motor truck is subjected to much more vibration than a pleasure car, and considerable more attention should be given to the running gear parts, as these may become loose much sooner than on the pleasure car, where all of the load is carried by very resilient pneumatic tires.

No treatise on automobile repairing would be complete without showing details of the Ford model T automobile, which is the most widely used motor vehicle in the world. The reader's attention is directed to the very clear sectional view shown at Fig. 343 for an idea of the arrangement of parts on this universally used motor car. The various parts are clearly outlined and may be located by following the leader lines to their termination at the arrow point. The other end indicates the name of the component. The plan view at Fig. 344 gives an idea of the appearance when viewed from the top.

Dismantling a Chassis.—The various steps incidental to dismantling a motor car chassis to give all parts a thorough overhauling is shown at Fig. 345. The plan view showing the appearance of the chassis of a Locomobile car at A denotes the appearance after the body and fenders have been removed. It is always ad-

visable to remove the body and the mud guards before any work is done upon the chassis, and in case of an extended overhauling much time can be saved by sending the body and guards to the paint shop while work is being done on the chassis. This is desirable because the finish of the body is much more important than that of the chassis parts, and it takes more time for the painter to do an enduring painting job on the body than on the running gear. The next step is to remove the running boards and running board irons, if these members are fastened to the frame by bolts. If the running board supporting members are riveted to the frame, it is not necessary to remove these unless the frame side member is to be re-enforced. The wheels are removed from the front and rear axles and the frame supported by special jacks. These may be easily made by using substantial cast iron base plates about a foot in diameter in which a piece of two-inch pipe is screwed. A sliding arm of cast iron made with either a cam or gib keylock, or having a strong set screw to keep it in place when it is set at the proper height, is adapted to move up and down the pipe. In some cases holes are drilled through the pipe and a stop pin used through it on which the supporting arm is allowed to rest. These frame supports have the advantage of not interfering with the removal of the various chassis components as they support the car weight directly under the frame sides instead of through the medium of the axles and springs as the ordinary lifting jacks do. Four of these stands are used, two on each side of the car.

The appearance of the chassis with the running boards and wheels removed is shown at Fig. 345, B. The next step is to remove the radiator, the steering gear and the change speed gear controlling members. The clutch and brake pedal cross shaft may also be taken from the chassis at this time. This leaves the frame in the condition shown at C, Fig. 345. The next step is to take off the rear axle, including the propeller drive shaft, torque member and radius rods. The chassis then has the appearance as at D. After the removal of the change speed gearing the parts left are shown at E. The dashboard assembly and the engine are next taken off the frame, which leaves the frame as shown at F. At this time only the front axle and rear springs are retained. When all the

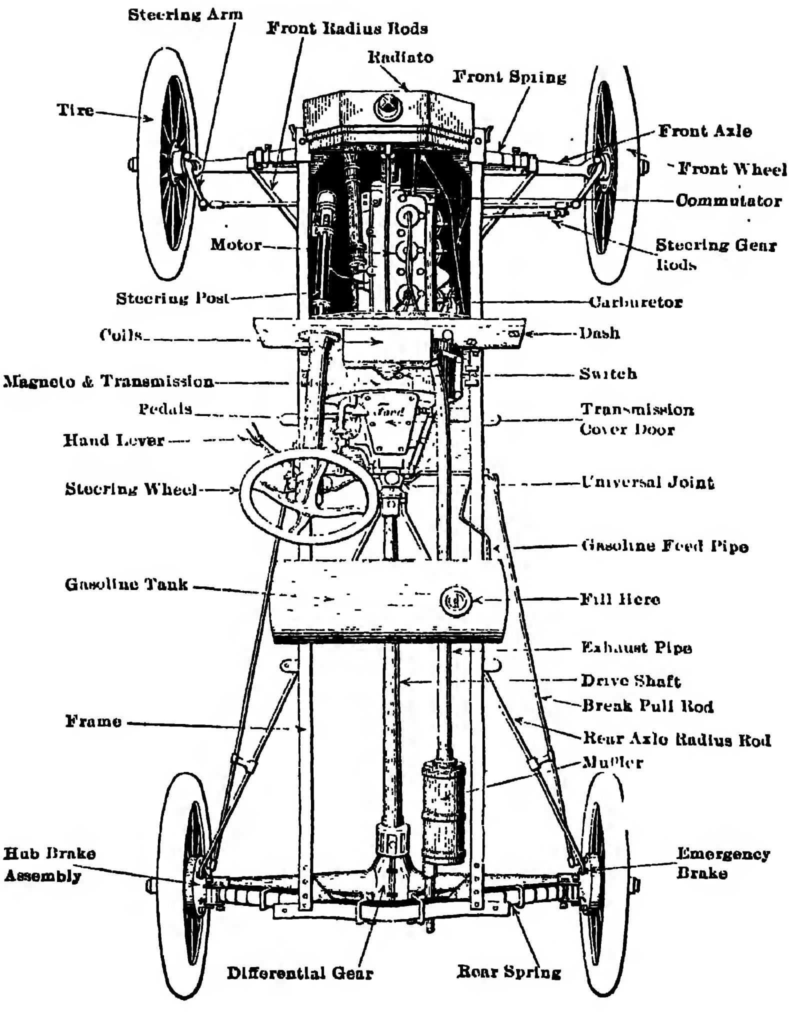


Fig. 344.—Plan View Showing Location of Chassis Components of Ford Model T Car.

parts, including the front axle and the front and rear springs, are removed nothing but the bare frame, as shown at G, is left.

It is seldom necessary to strip a car down to the point shown at F or G, unless repairs are needed on the frame and the injured parts cannot be reached with the various power plant and transmission units in place. The reason for the removal of such parts as the motor, steering gear, change speed gear box and axles is that these can always be more conveniently worked on if supported on special stands adapted to receive them. Many of these have been described in an earlier chapter when speaking of shop furniture. Obviously the process of reassembling would be just the reverse of that outlined for taking the chassis apart. Starting with the bare frame shown at G, one would add the springs and front axle as at F, then install the power plant and dashboard assembly as at E, couple up the change speed gearing as at D, then put in the rear axle and the various connections as at C. The steering gear, radiator and various control rods and levers would then be put in place, as well as the muffler assembly, which would bring the chassis to the almost completed state outlined at B. The addition of the running boards and their supporting irons, the wheels, brakes and brake rod linkage, would then complete the chassis as shown at Fig. 345, A.

The various retention means, such as bolts and lock washers, as well as other forms of lock members, are described in the chapter dealing with special repair processes. The most common form of nut retention is by employing a split pin in connection with a castellated nut. A number of tools have been described for cotter pin removal, but many owners of cars do not possess anything but the tools furnished with the repair kit. Two methods of doing this work easily which do not require the use of a special tool are shown at Fig. 346. One of the best ways for getting an ordinary split pin out of the hole is shown at the top of the illustration. The pin is grasped between the ordinary combination plier jaws and a hammer is used against the plier to draw out the pin. The other method, which is shown below, consists of inserting a steel drift pin or nail set through the hole in the cotter pin head and then striking the drift with a hammer. It will be found that the

removal of the pin will be expedited considerably by squeezing the ends together, if they are spread, with the pliers before attempting to withdraw the pin from the hole.

A very good method of supporting the front or rear end of a motor car frame, if there are projecting parts, is shown at Fig. 347. This consists of placing a flat bar of steel under the frame just back of the spring horns, and by using a wooden horse or trestle under the iron bars to support the weight of the vehicle. The springs may then be taken off without disturbing the axle and steering connection, if these are the only members that demand attention. If it becomes necessary to move the car at any time while the horse is in place, the space between the frame and axle may be filled by blocks of wood, which become temporary spacing members and which will permit the weight of the car to rest on the axle. The same method may be used in supporting the frame in event of a complete overhauling being necessary.

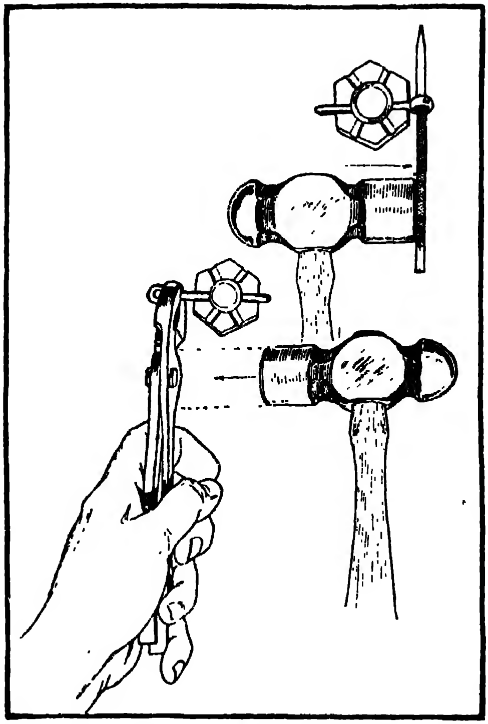


Fig. 346.—Simple Method of Extracting Split Cotter Pins.

Straightening Bent Frame Member.—One of the most common repairs to a frame is straightening a spring horn or dumb iron in event of a collision. A very simple and effective method of performing this work is shown at Fig. 348, providing that the frame

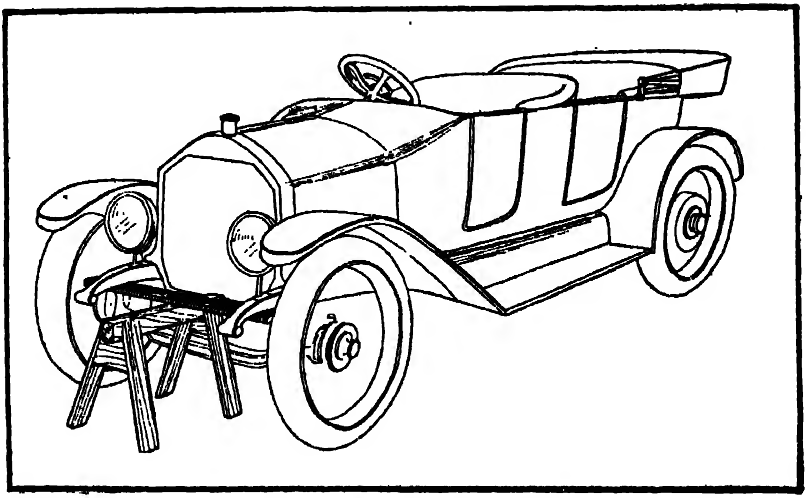


Fig. 347.—Outlining Method of Supporting Front End of Motor Car Frame When It is Desired to Remove Either Front Springs or Front Axle.

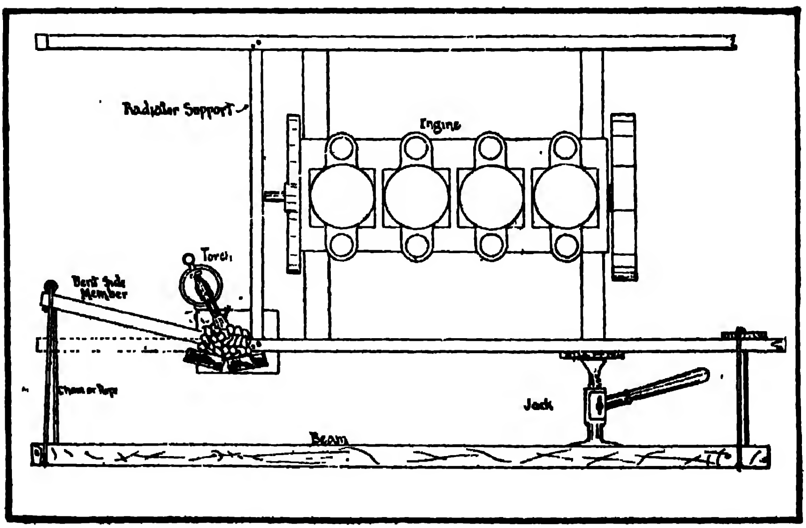


Fig. 348.—Showing Method of Straightening Bent Frame Side Member.

is bent forward of the radiator support and that the shock has not cracked or materially injured the metal. If the frame side is cracked it will be well to straighten it to its original form and then fill in the cracks with new steel by the oxy-acetylene process. If the frame is merely bent, straightening to its original form will be all that is necessary to effect a permanent repair. The radiator should be removed, as well as the front axle and the springs. The front of the machine is supported by blocking under the frame members or by any suitable stand. The body should be raised from the chassis about four inches at the front end so that a loop of chain can be passed around the frame member to act as an anchorage for a piece of joist used in straightening the side members.

A piece of sheet steel is placed under the frame and supported by the box, the top of which has been covered with about 3 inches of sand. A rough furnace may be constructed of firebrick and the frame covered with charcoal, a slab of firebrick serving to keep the heat confined to the bent portion of the frame. A large gasoline blow torch is employed in connection with the burning charcoal and sufficient heat is applied to bring the frame side to a cherry red heat for several inches each side of the bend. The torch is set aside and while one man carefully manipulates the jack, which is best placed against a piece of board resting on the frame member at the point where the engine support is bolted or where a cross brace is riveted, an assistant facilitates the work by hammering and contouring the heated section to bring it back into shape. A blacksmith's "flatter" should be interposed between hammer and frame in order not to dent the frame side, as might be done if the hammer blows were directed against the heated member. The straightening can be done only while the frame member is hot enough to show color, and as soon as the redness is lost the torch must be again applied to heat the bent section before any further work is done. A block of wood may be interposed between the frame channel so the chain or bar loop at either end of the beam does not crush in the metal where pressure is applied. The sketch plainly shows the manner of doing the work and the use of the tools to effect a very satisfactory restoration.

Trussing Weak Frame.—The frame side members sometimes

sag after the car has been used for a period, especially if it is operated at high speeds over rough roads, or in the case of a motor truck that has been made to carry overloads. A weak channel section member of this character can be made stronger by either of two methods. It may be re-enforced by a plate riveted to the

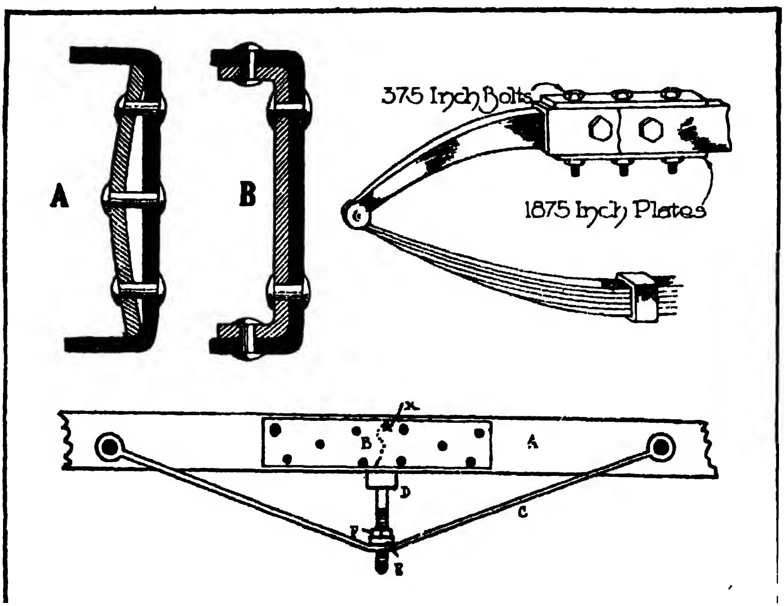


Fig. 349.—Methods of Repairing Cracked Frame Side Member.

interior or it may be trussed by truss bar and turnbuckle arrangement. Sometimes a plate is added to both inside and outside of the frame and the whole held together by rivets or bolts. The best method where conditions permit is to use the inside re-enforcement as shown at Fig. 349, B. When correctly applied, and proportions properly worked out, this results in the greatest strength. The sketch shows two common methods, one correct, the other incorrect. Instead of using a wide flat plate, slightly greater in height than the inside distance between the upper and lower flanges of the channel, the re-enforcing member should fit the interior of

the channel closely, as at B. The wide plate method shown at A is wrong for two reasons, the first being that the main frame gains little strength from the plate and but a small amount from the fastening, where the mounting is such that these are subjected to internal stresses which may break them without considering the external forces acting on the frame. The fillet in the corners of the channel make the accurate fitting of such a plate a very tedious job, so that usually a compromise is accepted and the re-enforcing members driven in by brute force.

The repair plan outlined at B is a much better one, as in this a wide sheet of fairly thick metal is forged to channel shape so it fits the inside of the frame closely. The contour of the interior of the section may be readily found by making a template of light sheet metal. The re-enforcing member should be just a trifle larger than the interior of the frame, as it must be driven in place when assembled. It is then attached to the side as well as at the top and bottom of the channel by bolting or riveting. These fastenings lend much stiffness and strength while the placing of the retaining bolts or rivets will not allow of any shifting of parts after the re-enforcing plate is once installed. While it requires a little more time to make than the former, it will give considerably more strength and last many times as long. If the weak spot or crack is at only one point, a ten-inch plate will do, but if the weak zone is wider than this greater lengths must be used. The method outlined to the right of B involves placing plates on both sides as well as top and bottom of the spring horn. This repair is an unsightly one and a much better repair can be made by using the autogenous welding process instead of the clamping plates. No matter what process is employed, it is necessary to bring the injured portions of the frame together in the same relation they occupied before fracturing.

Sagging side members in cars of the form where the engine and gear box are separate units may not be apparent except by difficulty in gear shifting, owing to lack of alignment between the clutch and gearset shaft or binding in the gear shifting mechanism. This condition is specially noticeable in cars using wood frames. When the construction permits, a truss rod forms a very effective

means of straightening up a sagging side member and preventing a recurrence of that trouble. The illustration at the lower part of Fig. 349 shows one method of re-enforcing a side member, though the adjustable member, to draw the frame together, can be just as well made in the form of a turnbuckle and placed on one side of the brace rod. In the cut letter A indicates the side member, B the repair plate with sliding bolts and lock washers, C the truss rod and manner of attachment, D a bolt with an enlarged supporting head, E the flat enlargement of the truss rod to secure sufficient metal to have a hole to receive the truss bolt D, F a tension nut on the truss bolt. The advantage of this repair is that it may be made at any country blacksmith's shop, whereas the fitting of a turnbuckle usually requires machine shop facilities. The bolt is placed under the cracked portion indicated by X, and tension is produced in the truss rod C by screwing down the nut F on the bolt D. The truss rod may extend from the front to the rear end when the side member is sagging, and would be longer than that indicated for supporting the cracked side members. In this case the truss would resemble that used in bracing freight car floors, in that it would have two supporting members in the form of castings under the frame spaced far enough apart so there will be a length of straight rod joining them in which the turnbuckle would be placed. The best method of anchoring the ends of a truss rod to a frame is to make an eye member in each end of the rod and to have a forged I member with a flattened portion that can be fastened to the frame side by substantial bolts to attach the rod ends to. Care should be taken in tightening up the truss members not to buckle the frame side rail to the other extreme after it has been straightened out.

It is not unusual to find the rivets at the corners of a frame or those holding cross members and gussets or re-enforcing plates loose. If they are not very loose, satisfactory repairs can often be made by peening them over again, using a heavy hammer and a suitable anvil or rivet set to receive the force of the hammer blow. A rivet set for frame work may be easily made by taking a large bar of square or round section iron or steel, three feet long and two inches in diameter, and turning up one end at right

angles to the bar about three or four inches back from the end. Both ends are then tapered down so that the area is approximately an inch square. A suitable counter sunk depression is then made to receive the rivet head at each end of the bar; one may also be placed on the side of the bar about an inch from the end. This will permit the use of the same bar in corners as well as on rivets so

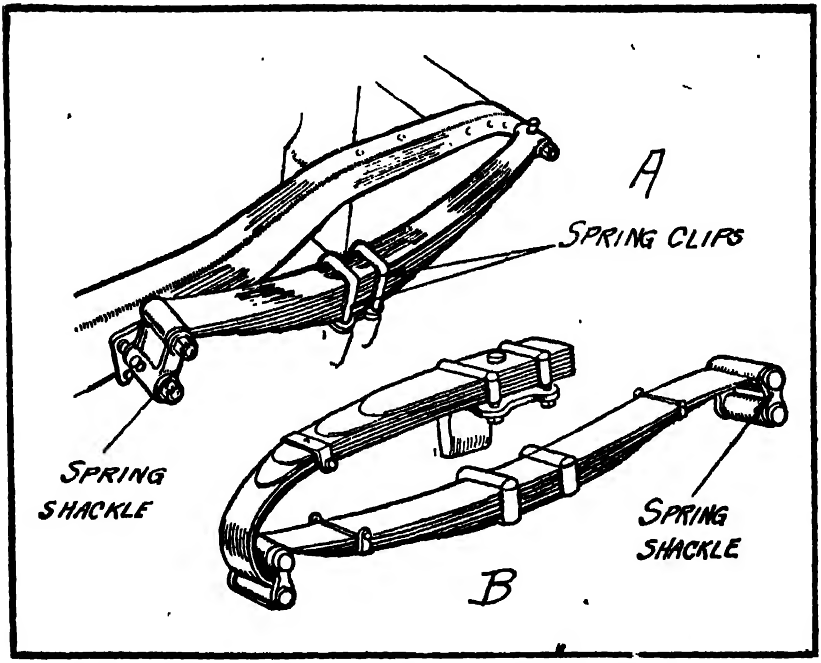


Fig. 350.—Showing Construction of Semi-Elliptic and Three-Quarter Elliptic Springs.

placed that the length of the bar does not prevent it being held against the rivet heads. Two men are required to do a good job of riveting, one to manipulate the riveting hammer, the other to hold the bar up against the rivet and absorb the impact of the hammer. If the frame members are very loose it indicates that the rivets have become reduced in diameter and partially sheared. In cases of this kind nothing will be gained by peening the rivet

heads over more. The only safe remedy is to chip off the rivet heads with a sharp cold chisel and then knock them out of the holes with a steel drift. The holes are then drilled to the next larger standard rivet size and new rivets secured. These are usually of Norway iron, and should be heated to a red heat in a gas or coal forge before being headed up.

Care and Repair of Springs and Spring Parts.—There is no more annoying condition to the motorist who desires a smooth running and quiet car than continual squeaking noises due to dry running gear components. If the springs squeak continuously, and their complaint does not cease after a thorough oiling of the suspension joints and shackles, there is no cure other than introducing lubricant between the leaves. The best method of doing this is to take the springs apart and place liberal quantities of graphite grease between the leaves before assembling them and remounting. Before commencing operations the chassis should be securely supported and blocked up to take the load off both springs at the front or rear, as the case may be. A good method of doing this is to lift the car by jacks and support it from the spring hangers by a heavy iron bar or wooden beam placed directly under them and between the springs and the frame, as shown at Fig. 347. The weight may be taken by a wooden trestle or suitable blocking. Another method is to relieve the weight of the car by raising the cross piece with a chain fall or portable crane. When the load is taken from them, the springs will assume their natural position, and it will be comparatively easy to release the spring clips holding them in place at the axle and the shackles and take them apart. When reassembling, fill up all of the holes in the shackles and bolt eyes with grease. While the spring leaves are separated it will be well to remove all rust from the surfaces by scraping and then smoothing with coarse emery cloth.

Various types of springs that have received general application are shown in illustrations Figs. 350 to 353, inclusive. That at 350, A, is one of the most popular spring types and is called the "semi-elliptic"; the form at B is known as the "three-quarter elliptic." A platform spring suspension consisting of two semi-elliptic springs parallel to the frame side member and one semi-elliptic spring par-

allel to the rear cross member joined together by double shackles is shown at Fig. 351. The cantilever form of spring which is now assuming some prominence is shown at Fig. 352. The "full elliptic spring," outlined at Fig. 353, is not as popular as it used to be, and is found on cars of several years back rather than on present-day models. There are two notable exceptions, however, the Franklin and the Jackson, which still use the full elliptic construction.

It will be observed that there are a number of points about springs that demand attention besides the spring leaves. These include the spring supporting shackles, the shackle bolts, the spring

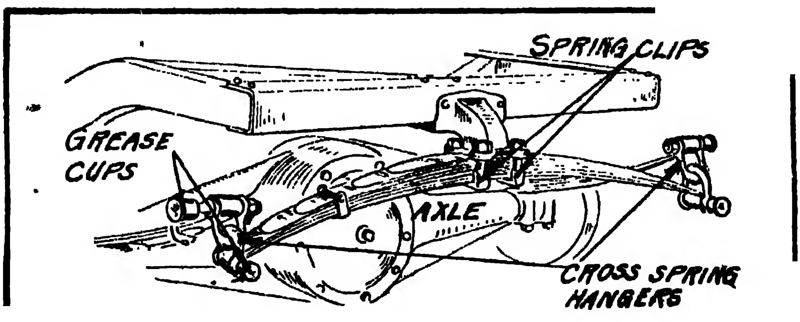


Fig. 351.—Arrangement of Platform Spring Suspension.

retaining clips, and the rebound clips. There is considerable diversity in the design of the spring leaves and the finish at the end of each member. The nomenclature of the various finishes recommended by the S. A. E. is clearly illustrated at Fig. 354, A. The usual construction of a spring clip is shown at B. The approved type of spring shackle is shown at C. As will be apparent, this member consists of two side links and two bolts holding them in place to the spring eyes. On modern cars the bolts are provided with small grease cups and with passages drilled through them, through which lubricant may be introduced to the bearing surfaces. The spring eyes are bushed with bronze bushings, which may be renewed easily when worn. On cars several years old this pre-

caution was not taken except on those high grade makes where s cost was such as to warrant the expense. To-day, practically a. cars, even though selling at moderate prices, are provided wit this refinement of detail. Where no provision is made for lubri

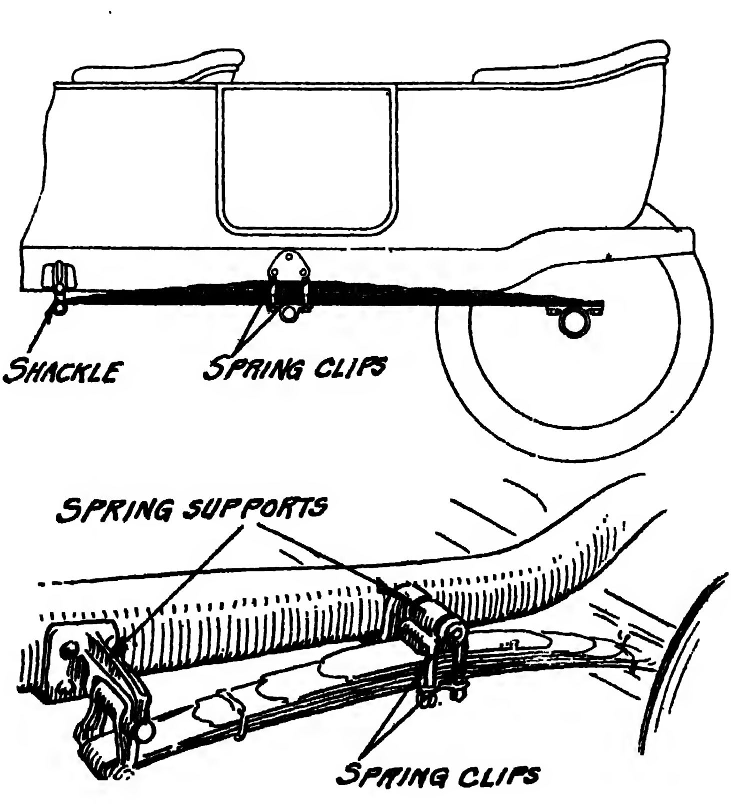


Fig. 352.—Cantilever Spring, as Used on 1915 Automobiles.

cating the shackle bolt, and where the hard steel spring eye bea directly against it, it is not unusual to find these bolts worn ha way through after a season's use. Even when the bolts are of th lubricated type, it will be found advantageous to take them ou

occasionally and clean out any hard grease that may have accumulated in the passages or between the bolt and the bushings. With the old construction the bolts were usually left soft so as not to wear the spring eye. For this reason they wore rapidly. The only remedy is to replace the worn bolts with new ones of the proper size.

If dismounting the springs is considered to be too strenuous a task, graphite and oil may be introduced between the leaves by

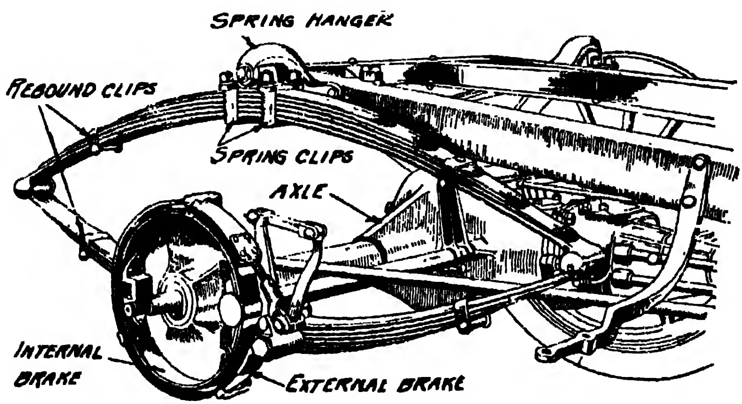


Fig. 353.—Application of Full Elliptic Springs for Supporting Rear of Automobile Chassis.

using some form of a spring spreader. Block up any lifting jack so that when the ram is at the lowest point it can just be introduced between the blocking and the lower flange of the frame at the spring hanger supporting the spring first operated upon. If the jack is screwed up until the tire is raised clear of the ground this will cause the weight of the wheel and a portion of the axle to be suspended from the frame through the spring, and if no rebound clips are provided and the spring retaining clips are loosened slightly, the leaves will probably be easily separated by the introduction of a spring spreader. The graphite grease may then be introduced between the leaves with a piece of tin or oil may be applied with a hand oil cup. A handy device for use

in garages, and one that can be easily made by the repairman, is shown at Fig. 355, A. This is easily forged out of soft steel, and if necessary the wedge-shape tips may be case-hardened. The handle should be made of such length that no great amount of strength will be needed to spread the springs. The method of use is very simple and is clearly shown beneath the cut of the tool. Another form of spring spreader which may be procured of any

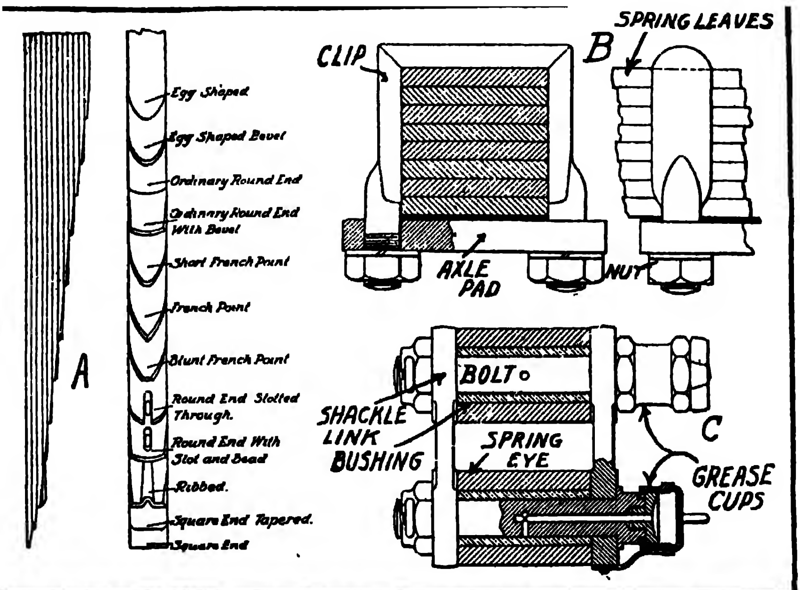


Fig. 354.—A—Defining Designation of Finishes of Spring Leaf Ends. B—Showing Construction of Spring Retaining Clip. C—Section of Spring Shackles Using Lubricated Shackle Bolts.

accessory dealer and the method of use is shown at Fig. 355, B. This has the advantage of being readily adjustable for different widths of springs.

A simple device that has been recently introduced for the purpose of feeding lubricant between the leaves of a spring continually, and just where the lubricant is needed, is shown at Fig. 355, C. This is known as the Dann insert, and is a piece of special

flexible metal, having machine-punched, staggered holes as shown. These holes are filled with a special grease having a melting point of over 200° Fahr., and on both top and bottom of the metal strip a piece of prepared wax paper is placed to retain the lubricant lodged in the holes of the metal strip. The strips are cut to the proper length and placed between each pair of spring leaves. The inserts may be procured in sets, all cut to proper length, for the springs of standard cars. It is stated that after the inserts are placed in a spring the rubbing action tends to wear off the wax paper and permits the grease to flow between the spring leaves. As the grease is retained in pockets, it is not apt to run out at the sides of the leaves and spoil the finish of the car.

The following advice on the care of motor truck springs was taken from a paper read by John G. Utz before the S. A. E., and as many of the points mentioned therein apply just as well to the frame supporting members of pleasure automobiles, they are retained and can be followed to advantage by the motorist and repairman as well as the motor truck driver.

Keep Clips Tight.—Spring clips should be inspected at least once a week and tightened as much as possible. If the clips become loose, the spring will break between the clips. If there is undue stretching of the clips, the difficulty might be overcome by having new clips made of better material, as it is always cheaper to replace clips which are too light than to have broken springs as a result. The bearing place upon which the spring rests on the axle should absolutely conform to the curvature of the spring at that point, as sufficient bearing surface is just as important as tight spring clips.

Hints on Repairs.—If a spring plate should break, it is important to have it repaired or replaced immediately by a skilled spring maker. Quite often a break in a plate occurs at a place where it does not immediately cripple the entire spring, but it is simple to understand that the breaking of one plate throws extra work upon the other plates which will break in turn. If one of the intermediate plates should break at the center bolt, the spring clips should be tightened down until it is possible to have

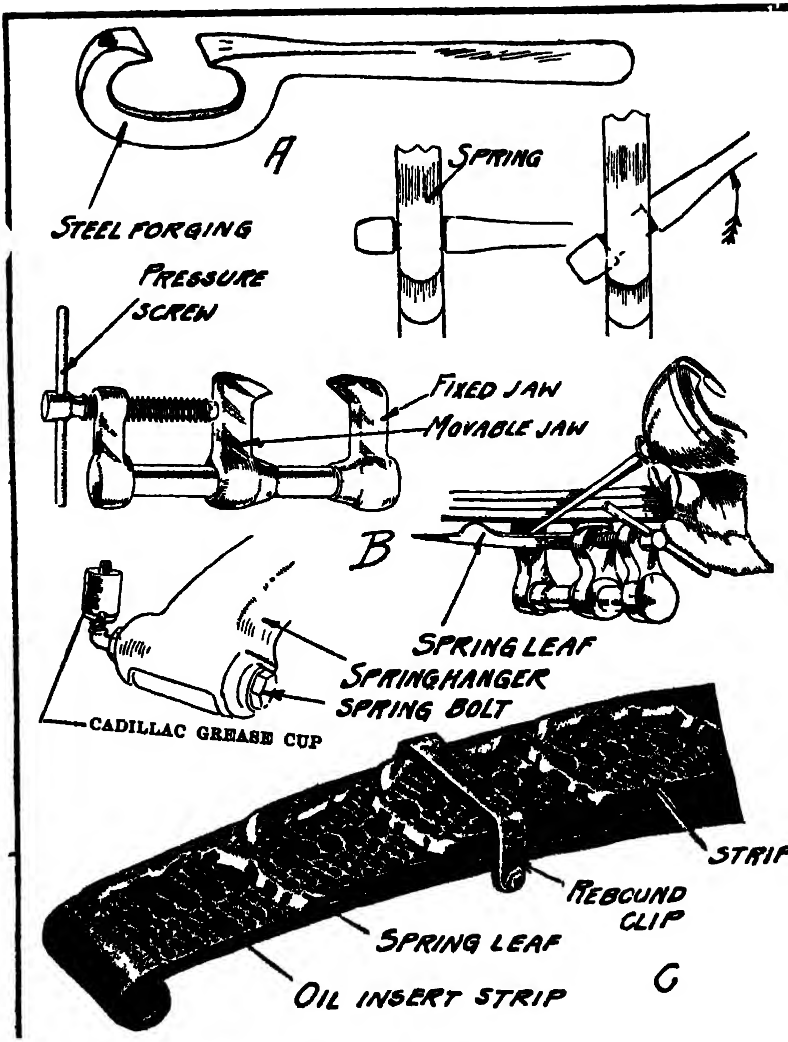


Fig. 355.—Methods of Inserting Lubricant Between Spring Leaves to Prevent Squeaking.

the break repaired. Very often rebound clips are loose and broken. Missing rebound clips very often result in broken main plates.

On chain drive trucks there is always an ample allowance for adjustment to offset the stretch and wear of the chains. As the chains become stretched to a great extent, it is wise to remove an entire link and then shorten the adjustment so as to keep the spring shackles (at each end of the spring) standing at about the same angle.

A spring is a complete unit as produced by the spring maker. The removal or addition of a plate entirely disarranges the grading of the original plates, and should never be practised under any circumstances. It is also very bad policy to replace a broken plate by any plate that happens to be of the same width as the spring. It is far more desirable to let a competent spring maker attend to the repair or replacement.

In view of the preceding, there follows a list of things to be observed in the operation and care of the truck, if there is a desire to give the springs a fair chance to offer their longest life.

Rules of Reason.—A.—Evenly distribute load. Prevent shifting of load. B.—Do not overload beyond rated capacity. The factor of safety allowed by the maker is for the owner's protection as well as the maker's. C.—A wheel out of round due to flat spots on a solid tire, imposes a severe and dangerous shock upon the springs. Keep the wheels round. D.—Keep excessive side play out of shackles and hangers to minimize the lateral shock on the springs when on rough roads. F.—Give careful attention to all parts subject to friction. Keep them amply lubricated, as an excess of grease keeps the dirt out. F.—Take corners slowly, without or with load. G.—Back into a curbstone or platform gently as your radius rods might buckle and throw the jolt upon the springs. In driving the front wheels against a curb or any obstruction, the shock must be taken by the springs alone. H.—When loaded, drive gently over rough road or obstruction, remembering the frame is rigid and the springs must take the distortion. I.—Drive at moderate speeds at all times. Remember solid tires have little resiliency. J.—If you have to tow a car, or have your car towed, hitch the tow-rope to

the frame, not to the axle. K.—If an accident occurs, and a spring hanger, or the frame near the hanger is bent, have it straightened at once. A spring distorted by a bent hanger is liable to break under load. L.—When adjusting chains, remove a link when the adjustment would throw the shackles to a bad angle. M.—Keep spring clips tight at all times. If a center bolt should break, due to loose clips, replace it at once. N.—On a crowned road, drive as nearly in the center as possible, as driving to the right throws an extra load on the right-hand spring.

Compensating for Steering Gear Deterioration.—One of the most important parts of the chassis assembly and one that should never be overlooked in overhauling is the steering gear, because it is upon this important control element that the safety of the car and passengers depends. The steering gear should always be kept adjusted to the point where the wheel will turn freely and yet not have any back lash. The steering gearing consists of the steering column, the wheel supporting knuckles on the front axle, the tie-bar that joins the steering spindles together and the drag link which acts to transfer the movement of the steering arm to the front axle members. Typical steering columns are shown at Fig. 356. That at A is the most common form and utilizes a worm at the lower part of the steering post to which the hand wheel is attached, meshing with the worm gear which actuates the ball arm. A sectional view of the reduction gearing is shown in the inset A-1. The other form of gear generally used is known as the thread and nut form and has a worm at the lower end of the post which rocks the steering arm sometimes called the "pitman" arm or "ball" arm by means of two half nuts, one of which moves up and the other down when the worm is turned by the hand wheel. This reciprocating motion of the half nuts is transferred to the pitman arm by an oscillating member against which the ends of the half nuts bear and which is attached to the shaft that rocks the steering arm.

Another form of thread and nut steering gear is shown at Fig. 357. In this the nut is a full member encircling the screw and carrying projecting pins which engage the forked arms attached to the steering arm actuator. As will be apparent, when the screw is turned by the hand lever, the nut is raised or lowered, depending

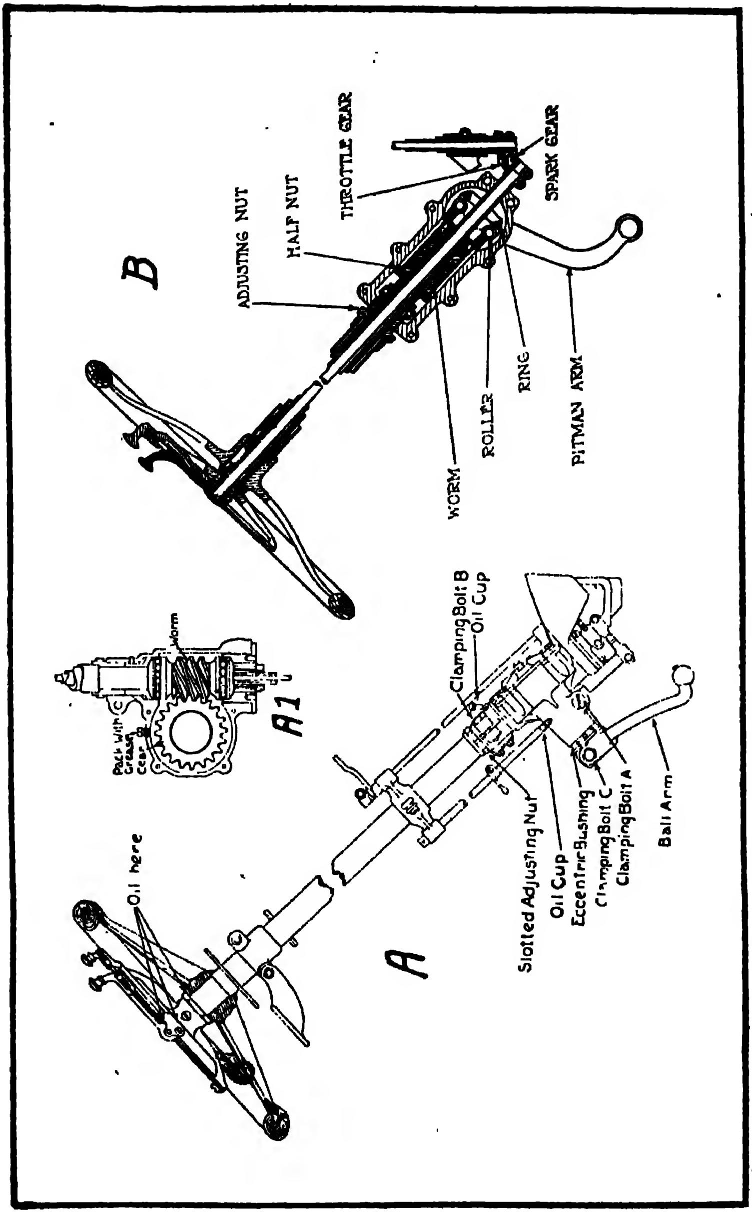


Fig. 356.—Outlining Construction of Typical Steering Gears. A.—Worm and Sector Type. B.—Screw and Nut Pattern.

upon the direction in which the screw is turned. This up and down motion of the nut is transferred to the steering actuator through the medium of the small pins working in the forged yokes attached to the steering arm actuator shaft. The steering gears described are of the irreversible form, i. e., motion of the road wheels does not affect the hand wheel. Many other arrangements have been used for steering gears, one of the popular forms being the bevel pinion and sector arrangement used on Reo automobiles which is shown at Fig. 358. The bevel pinion moves the bevel gear sector back and forth as it is turned, this motion being transferred to the steering arm attached on the same shaft to which the bevel gear sector is fastened. While this steering gear is effective, it is not irreversible and motion of the road wheels may move the steering wheel.

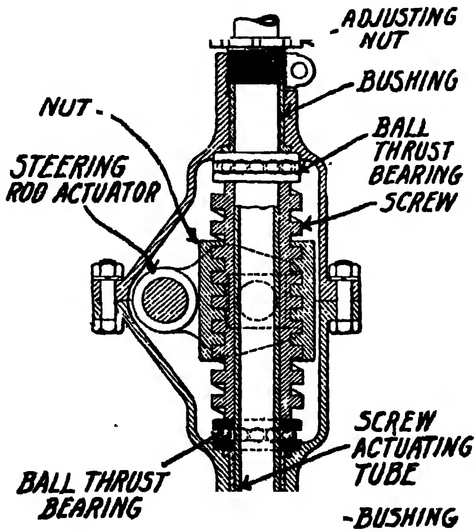


Fig. 357:—Internal Construction of Screw and Nut Reduction Steering Gear.

The common fault with a steering gear of any type after it has been in use for a time is back lash in the reduction gear. By this is meant the ability to turn the hand wheel back and forth a certain portion of a revolution without effecting a corresponding movement of the front wheels. There are a number of points where this back lash may exist. It may be present in the reduction gear of the steering column itself or may be due to depreciation or poor adjustment of the various rod ends in the steering linkage. Considering first the reduction gearing of the worm and worm gear type, as shown at Fig. 356, the point that

will wear soonest is that portion of the worm gear that meshes with the worm when the wheels are set for straight ahead going. The reason that this depreciation is present at this point more than at the other teeth of the worm wheel is because this point is most widely used, the movement of the worm being very slight except when turning a corner. Attempts are often made to take out this back lash by bringing the worm gear into closer arrangement with the worm by the use of eccentric bushings in which the worm wheel shaft is supported. The eccentric bushing serves very well if the back lash is due to poor adjustment rather than depreciation of the worm wheel teeth. It is possible on most gears to remove the steering arms, give the steering wheel a half turn and then replace the full worm wheel so the unworn portion opposite to the worn teeth will be brought into engagement with a comparatively unworn portion of the steering worm. The eccentric bushings in this case can be used to secure correct meshing of the worm and worm wheel teeth.

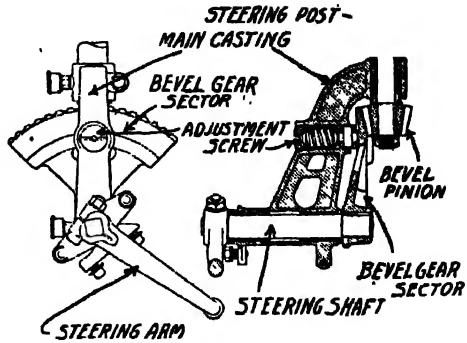


Fig. 358.—The Reo Bevel Pinion and Sector Steering Gear.

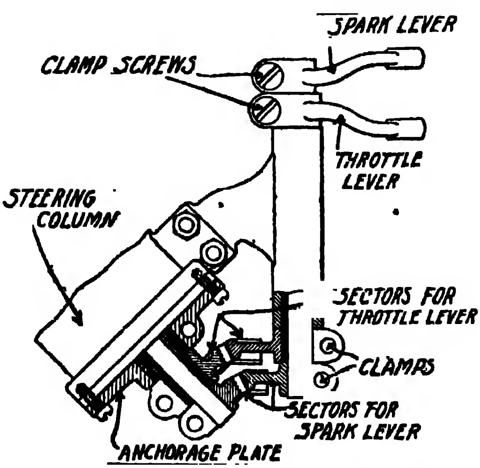


Fig. 359.—Showing Method of Operating Spark and Throttle Levers at the Base of the Steering Column.

As considerable end thrust exists at the top and bottom of the worm when the hand wheel is turned, ball thrust bearings are used to resist the end pressure and make the worm easy to operate. If these bearings become gummed up with dry grease or if the balls or races become roughened, the steering gear will work hard. If the ball bearings are not properly adjusted, an up and down motion of the steering post will be possible. If the steering post is loose in the steering gear case it is on account of wear of the plain bushing in which it turns. These bushings are best replaced by new ones when worn.

In the type of steering gear shown at Fig. 356, B, the half nuts are sometimes of babbitt metal and if not properly lubricated will deteriorate quickly. The hardened steel screw seldom shows any signs of wear and if lost motion exists it is generally due to depreciation of soft half nuts. The best method of repairing is to replace these with new members. In the type of steering gears shown at Fig. 357, the nut is usually made of hard bronze and the screw of hardened steel. Very little depreciation will exist in a gear of this nature unless lubrication has been neglected. There are two plain bushings which may wear that support the steering post, also two plain bearings on which the steering rod actuator shaft rocks. Any looseness due to depreciation of the bushings can only be eliminated by replacing with new bushings. If the nut becomes worn it is cheaper to supply a new one than to attempt to use the old one.

Back lash or lost motion in the bevel gear and sector steering gear shown at Fig. 358, when not due to depreciation of the plain bearings supporting the steering post and steering shaft may be compensated for by screwing in on an adjustment screw which carries a roll at its lower end, bearing against the back of the bevel gear sector. This tends to keep the pinion and sector teeth in contact and eliminates lost motion between them. Practically all steering gears are provided with grease tight casings and should be packed with lubricant at least every season. The plain bearings of most steering gears may be lubricated through the medium of compression grease cups as shown at Fig. 358, or oil cups as shown at Fig. 356, A. If care is taken to supply these bearing points with

the proper quantities of lubricant, but little trouble will be experienced due to depreciation of the plain bearing.

Many steering gears have the motor speed control levers carried above the hand wheel by a fixed sector which is supported by a tube passing through the center of the hollow steering post and clamped at its lower end to a non-rotating anchorage plate which keeps the sector from turning, as the hand wheel is moved in steering. Through the center of this anchored tube, another tube passes, in the interior of which is carried a rod as shown at Fig. 360, A. The short control lever is pinned to the rod passing through the center of the steering column while the long control lever which works on the outside of the segment is attached to the tube surrounding the center control rod. At the lower portion of these members a pair of small bevel sectors is carried as shown at Fig. 359. These sectors engage coacting members which operate the spark and throttle levers with which connections are made to the carburetor throttle and to the magneto contact breaker. When dismantling the steering column it is important to take out the center control tubes and remove all the rust that has accumulated between them. They are then smoothed and cleaned with emery cloth and coated with graphite grease before reassembling. In many cases, when movement of the control levers does not produce a corresponding motion of the timer or throttle, it is because the small levers or bevel sectors at the lower portion of the steering column have become loose on their actuating tubes or rods. The usual method of fastening these members is by friction clamps and the trouble is easily remedied by tightening the clamping screws more firmly after the various parts have been located properly. This may be done by setting the control lever at the retard position on the sector and making sure that the magneto contact breaker or timer is also at full retard position. When setting the throttle control lever, that member may be moved down to that portion of the sector corresponding to a closed throttle and making sure that the throttle is closed at the carburetor before tightening the clamping screws at all points. For instance, if the construction of the control levers is as at Fig. 360, A, and the lower portion of the steering post is as at Fig. 359, it will be necessary to tighten four clamp-

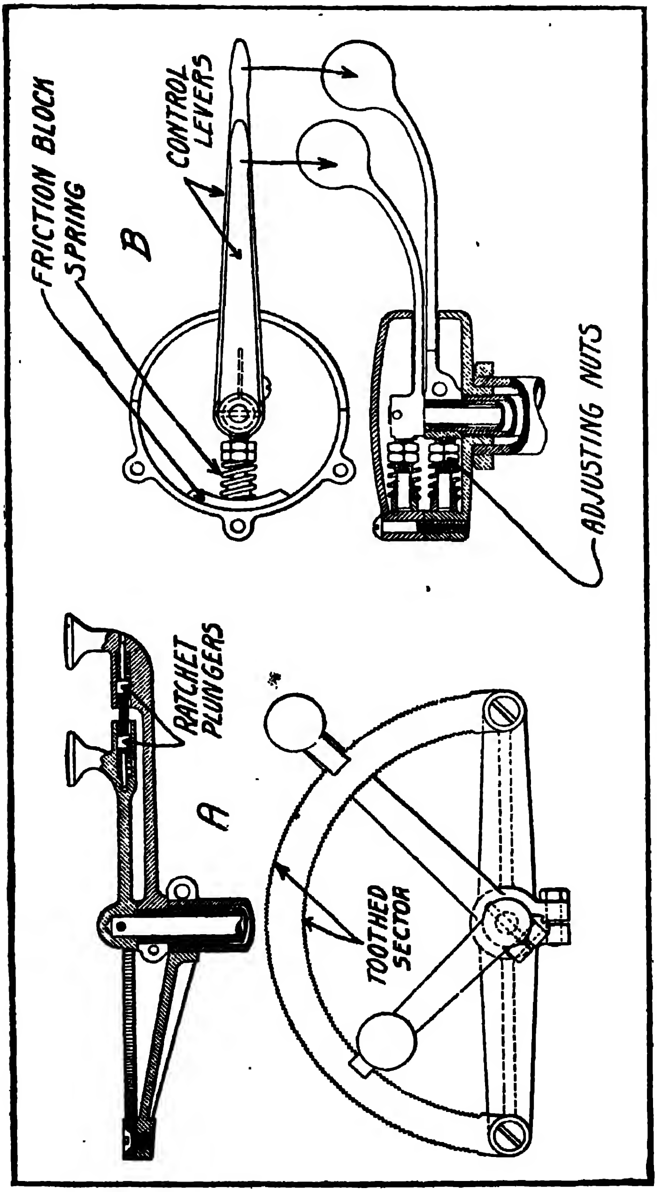


Fig. 360.—Showing Method of Supporting Spark and Throttle Levers at the Top of Steering Column.

ing screws in order to lock all parts firmly together. Two of these clamping screws are in the small bevel sectors while the others are in the levers, one at the bottom of the steering column, the other at the top. There may be a tendency at times for the entire toothed segment to turn with the steering wheel which causes the engine to race or which shuts it off altogether when turning a corner. This annoying condition is due to looseness of the sector supporting tube in the anchorage plate at the bottom of the steering column. If difficulty is experienced in keeping this tube tight, the trouble is due to deposits of rust between the sector supporting tube and the interior of the hollow steering column. The only remedy is to remove the sector retaining tube from the interior of the steering column and remove all rust deposits and coat the parts liberally with lubricant before reassembling.

The control levers at the top of the steering column are usually of the form at Fig. 360, A, though in some cases the construction shown at B is used. After the car has been used for a time the fine teeth on the sector may become burred over and the ratchet plungers may be rounded by constant friction with the teeth so the levers no longer stay in the places where they are set. The remedy for this condition is obvious. The teeth in the sector must be recut with a fine, three cornered file and the ends of the ratchet plungers must be repointed by grinding and the springs keeping them pressed against the sector should be strengthened by lengthening. When the friction block arrangement as shown at Fig. 360, B, is employed, any tendency to slip may be easily remedied by tightening up the spring tension adjusting nuts shown. The increase in spring strength augments the friction between the friction block and the side of the casing and serves to retard too free movement of the control lever.

A complete steering gear assembly with all parts clearly indicated is shown at Fig. 361. This shows the various points where back lash may exist and the resulting lost motion produce erratic steering. Taking these up in order, we have first the bolts supporting the wheel spindles in the yokes at the end of the axle, and the bushings in the wheel spindle itself. Next we have the pins and rod ends at the end of the tie rod, then the connections at each

end of the drag link. The point where the steering arm fastens to the steering gear should also be inspected to make sure that the arm is firmly clamped to its actuating shaft. On practically all cars, removable bushings are provided in the steering spindle which may be readily removed and replaced with new when worn. The ends of the tie rod have the bolts in them a tight fit and usually screw through the lower portion of the rod end. This means that

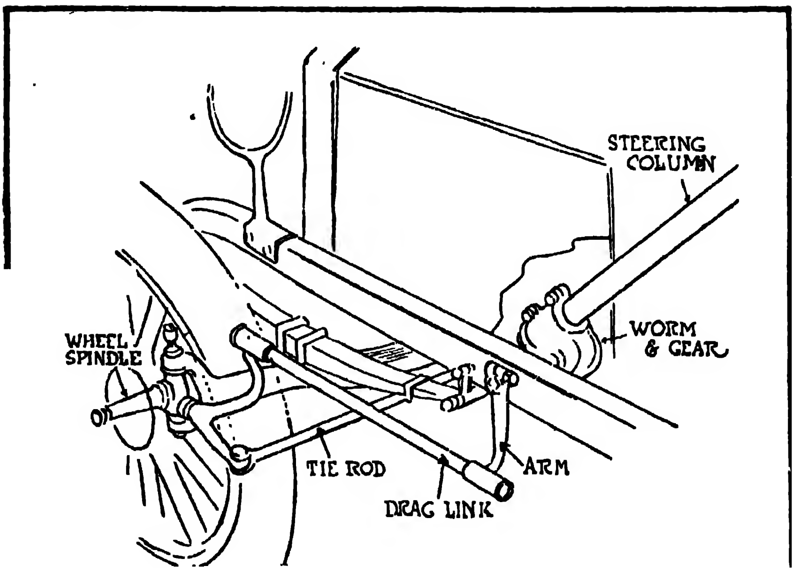


Fig. 361.—Showing Important Linkage of the Steering System.

the wear will come on the bushing in the steering arm that extends from the spindle instead of in the rod end.

The various steering gear parts that demand inspection are grouped at Fig. 362. The section at A shows a worm and worm sector steering gear with the upper half of the gear case removed to expose the gearing. This form is subject to the same trouble that the full worm gear and worm arrangement previously described is, but in event of wear of the sector teeth it is not possible to turn this over and obtain a new set of bearing surfaces. Practi-

cally the only remedy when this construction is followed, is to replace the sector with a new one. Of course, if the lost motion is due to poor adjustment, the usual eccentric bushing method of bringing the teeth into more intimate contact may be used. The arrangement of the rod ends used on the drag link and designed to operate in connection with the balls usually provided at the end of the steering arm is shown at B. As will be apparent, the ball rests between two plugs having semi-spherical depressions that act as a ball seat. One of these plugs is pressed against the ball by a substantial coil spring, while the other adjusting plug is brought in contact with the ball with a threaded adjusting plug. As the ball can only be introduced in the socket when the adjusting plug is out, which permits the small section of the steering arm to fit the slot, it will be apparent that even if this joint should loosen that it would be practically impossible for the ball to come out. In event of lost motion being manifested this may be easily taken up by loosening the clamp bolt or removing a split pin lock sometimes provided and screwing in the adjusting plug until all lost motion is eliminated.

The usual steering knuckle assembly is shown at Fig. 362, C. It will be observed that the bolt acting as a bearing for the steering knuckle and passing through the top and bottom of the steering yoke is provided with a grease cup at the upper part in order that the joint may be kept thoroughly lubricated. After the front wheel has been properly adjusted, if it is desired to find if there is any looseness in the steering knuckle, the wheel should be grasped by opposite spokes, one at the top, the other at the bottom and with the leverage thus provided endeavor to shake the knuckle on its supporting bolt. If there is any lost motion the bolt should be removed and its bearing surface examined. If it has been cut into or is reduced in diameter at the bearing points a new bolt should be provided. If the bushings in the steering knuckle are worn they should be driven out and new ones supplied.

Some inexperienced repairmen and many motorists are inclined to believe when they first see a "dished" front wheel that the front axle has sprung and that the construction is faulty. There is a very good reason for tilting the wheel as shown at Fig. 362, D. This

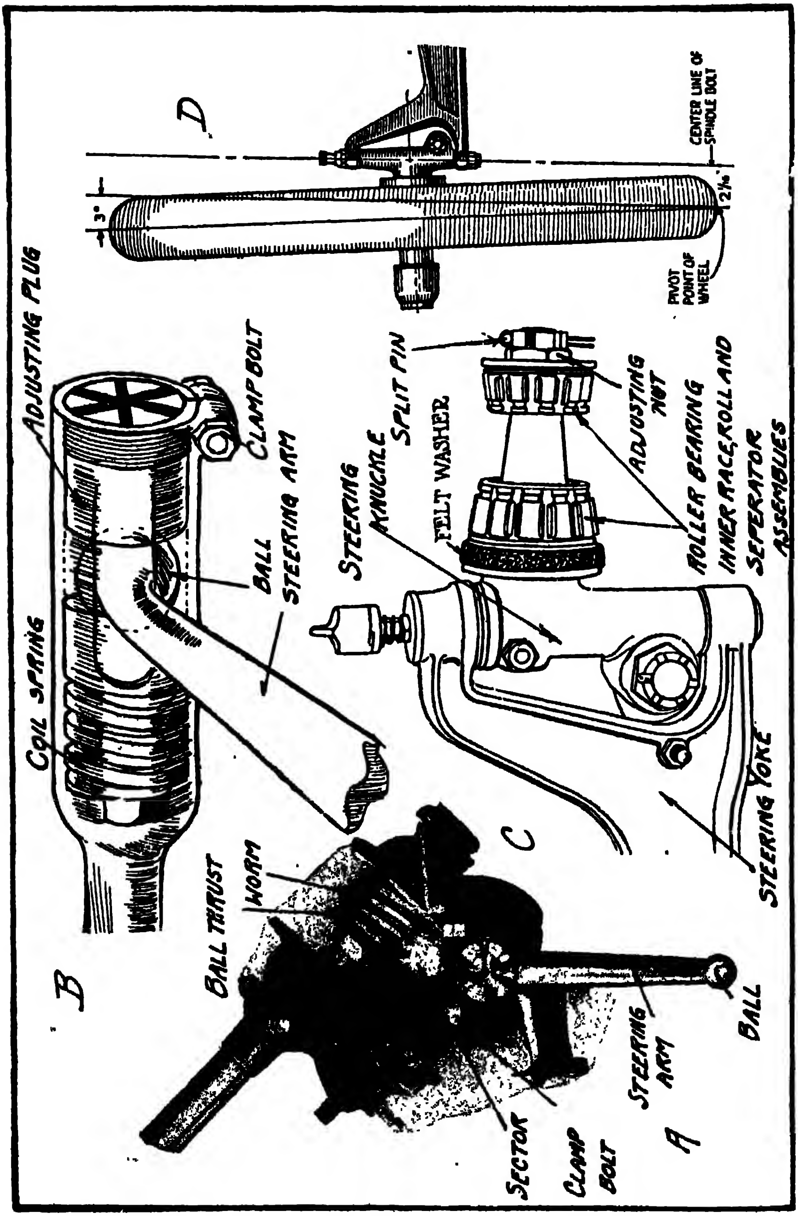


Fig. 362.—Showing Parts of Automobile Steering System that Demand Inspection when Overhauling.

is to obtain ease in steering and the usual angle of inclination is about three degrees. Without going into an involved explanation of the reason for doing this it may be stated that it is a mechanical principle that the nearer the center of the spindle bolt and the pivot point of the wheel are to an alignment, the easier the car will steer. If it were possible to bring the center of that part of the tire which is upon the ground to a point exactly under the joint of the steering knuckle the arrangement would be ideal. To secure this alignment or to get as near to it as is practical with the accepted Elliot steering knuckle construction, it is customary to tilt the wheel. In the case of the Ford car, a plumb line dropped through the spindle bolt would strike the ground about two inches from the pivot point where the wheel tire rests on the ground. The diagram makes this point clear. It is customary to find the front wheels of large cars dished in the same manner so this point should not be confused with lack of alignment in a horizontal plane which will interfere with correct steering and result in rapid tire wear.

Testing Wheel Alignment.—A splendid opportunity is present during the overhauling period for aligning the wheels and axles which should be done to make sure that they have not moved out of their correct position. But little apparatus is needed to make these trials, the outfit consisting of two chairs, two heavy pieces of wood, and two lengths of stout cord. One chair is placed at the rear of the chassis, the other at the front as indicated at Fig. 363. The chairs are located as near as possible to the center line of the machine and after the cords have been adjusted the chairs are spread apart enough to tighten the cords. In order to prevent movement of the chairs when they have been properly placed they may be weighted down with iron or steel parts. The important thing to do is to have the cords parallel to the frame side member and to have the member on the right just the same distance away from the right hand frame rail as the left hand cord is from the left hand frame rail. A common defect of alignment of the front wheels is shown at A. In this case the tie bar is too short and the wheels are nearer together at the back than they are at the front. The opposite to this condition is shown at B, in which case the tie

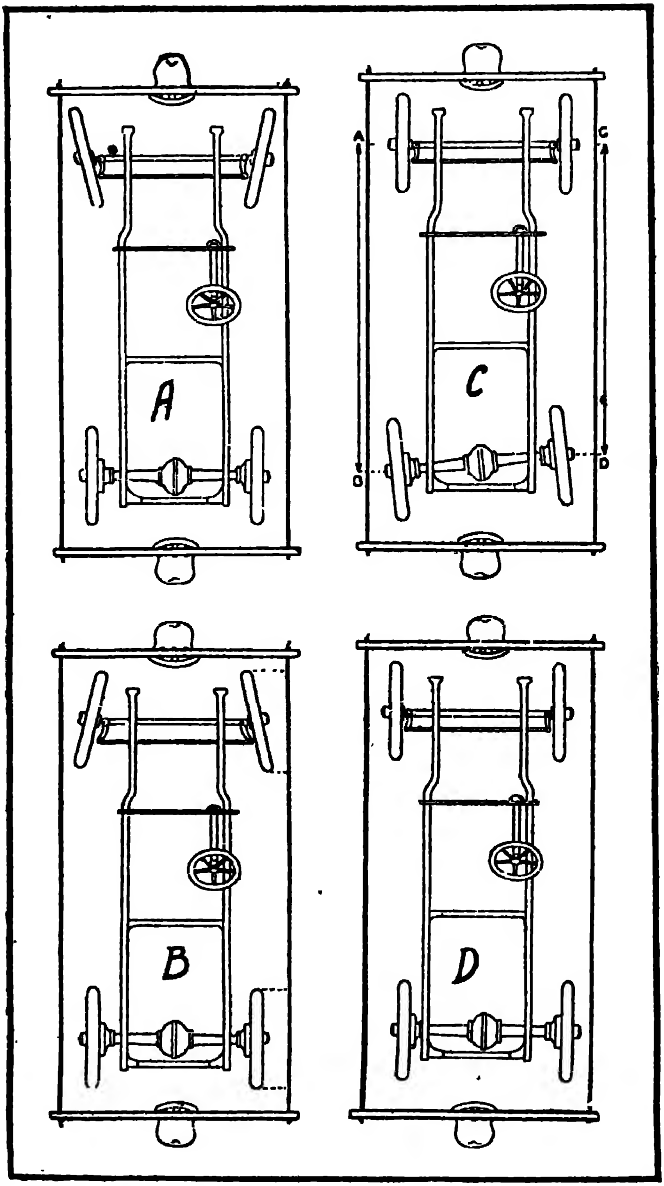


Fig. 363.—Methods of Lining Up Front and Rear Wheels.

bar member is too long and the wheels are nearer together at the front than at the rear. Either of these conditions will result in uncertain steering and will also produce rapid tire depreciation. Practically all tie bars are adjustable to a degree and steps may be taken to straighten up the wheels by either lengthening or shortening the tie bar as conditions demand. The sketch D also shows the method of testing a rear wheel for parallelism with the frame side member. At C, the method of measuring for alignment of front and rear axles is shown. As will be apparent the rear axle has shifted on its springs and the wheels are not parallel with the frame side members. At D, the axle has moved sideways due to shifting of the spring chairs and the wheels do not track, even though the rear wheels are parallel to the frame side member. It is important that the cords be stretched at a height equivalent to the center of the wheel hubs because some cars are made with considerable gather in the front wheels so that the distance at the rear of these members to the cords would be slightly less than at the front. Then again, many cars have considerable camber in the front wheels which means that the top of the wheels will lean outward, therefore any distances measured above the center of the hub will not agree with those taken below it. By stretching the cord along the center line of the wheel this trouble may be avoided.

Universal Joints.—The universal joint is an important element in practically all shaft drive cars, some constructions using but one joint if the propeller shaft is protected by a long housing while other systems employ two universal joints, one at each end of an exposed propeller shaft. Universal joints on many early cars were run exposed and considerable trouble was experienced due to rapid wear of the bearing parts. When exposed there was also considerable difficulty in keeping the joints properly lubricated. The modern forms are housed inside of a casing member, which is not only designed to exclude the dirt and grit from the bearing surfaces, but which is also depended on to retain lubricant. A typical universal joint assembly and the parts comprising it are shown at Fig. 364, A. The main parts of the joint are the yoke member A, and the disc member B. The yoke has bearing surfaces O and P designed

to engage two of the pins on the universal joint cross member J. The other two pins fit into the bearing members R and S attached to the disc B. The entire joint is housed in by the cover members

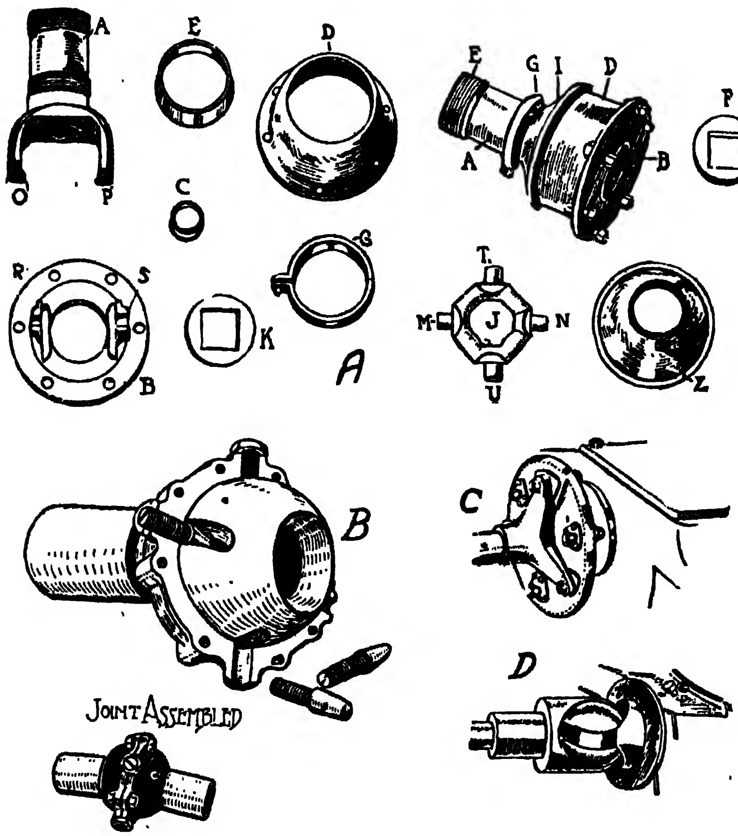


Fig. 364.—Universal Joint Construction.

D and Z. The driving flange B may be bolted to a corresponding member on the end of a change speed gear shaft or rear axle pinion drive shaft, while the sleeve member A, which is provided with either a square or splined hole as desired, fits on the end of the

propeller shaft. The points that will wear soonest are the pins M, T, N, U, carried on the universal joint cross J. When looking over universal joints it is well to make sure that the sliding points are free and that the sleeve member does not bind on the propeller shaft. Where two universal joints are used it is not necessary to have a slip joint at both ends and one of the sleeve members may be fastened securely to the propeller shaft.

The universal joint at Fig. 364, B, is called a roller bearing joint and consists of a hollow, slit bronze sphere attached to one shaft and a steel sphere, which may also be hollowed, attached to or formed integral with the end of another shaft. Four adjustable studs carrying conical rollers at their inner ends are equally spaced around the outside sphere. The inside ball contains four slots into which the pins project. The slots are so shaped as to allow free universal action and get no back lash at any point.

Another form of joint designed to give a flexible drive is shown at C. This is increasing in popularity and is found on a number of cars for final drive though it is more widely applied as a driving connection between the clutch or gear box or for magneto or electric starting generator drive. Two three fingered spiders having a suitable boss attached thereto to receive the end of the driving shaft are bolted to discs of leather, the fingers of one spider member being placed between those of the other and the leather disc securely held to each of the spiders. Owing to the flexibility of the leather it is possible to drive parts that are not in absolute alignment, though this form of joint is not suitable for use where there is apt to be considerable movement between the parts and the other types of universal joint are better adapted owing to allowing a greater degree of motion between driven and driving shafts.

A simple universal that has been adapted to some extent for light work is shown at Fig. 364, D. This consists of a ball shaped center member having machined slots into which suitably formed yoke members fit. This joint, while popular for machine tools, is not widely used in automobiles and it is illustrated in order that the repairman may be familiar with all practical forms of joints. The form shown at Fig. 365, A, is that used on the National auto-

mobiles and as two views are presented its construction should be easily understood. A driving member is keyed to the end of the transmission shaft and is securely held on the taper by a suitable clamping nut. The driving member is provided with two longitudinal slots in which square nuts or sliding blocks fit. These are mounted on a pin which is driven through the enlarged end of the propeller shaft. With this construction two joints are necessary,

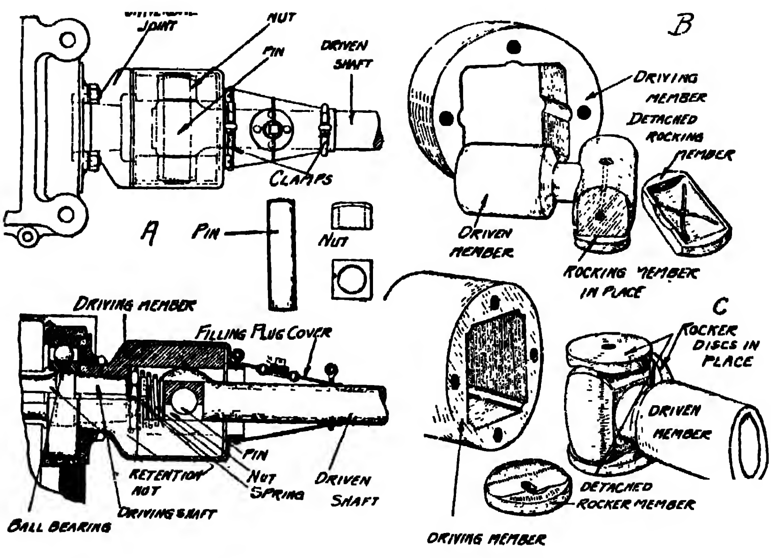


Fig. 365.—Construction of the Sliding Block Pattern Universal Joint.

one at the front end of the shaft, next to the gearbox, and another on the rear axle. After the joint has been in use for a time there may exist considerable looseness between the bearing pin and the hole in the sliding block and there may also be some depreciation of the slots in which the block slides. If the slots in the driving member are worn they should be machined out so that they are true and smooth though perhaps somewhat wider than they were originally. It is a very simple matter to make new case hardened blocks that will fit the enlarged slots in the driving member. The

manner of covering the joints in order to retain lubricant and keep out the dirt is clearly shown in the illustration. A pressed steel cover member is designed to fit over the driving yoke while the propeller shaft end is encased with a flexible leather cover securely clamped to both driven shaft and flange on driving member cover. In order to make it easy to introduce new lubricant to the interior of the joints a screw plug is provided which is screwed into a fitting riveted to the leather covering. Where two of these joints are used it is desirable to have the propeller shaft held so it may slide to some extent as the axle moves up and down yet not be loose enough to rattle. The desired end is easily obtained by interposing coil springs in each universal joint which bear against the enlarged end of the driven shaft and seat on the driving member retention nut.

Other forms of joints which provide a certain amount of universal action are shown at B and C, Fig. 365. In the former there are but two rocking members whereas in the latter there are four rocking members. The driving member of the joint consists of a sleeve having a square hole made to receive the end of the driven member which is a square or rectangular in cross section but having rounded faces as indicated. In the form at B, two of the sides of this "square ball" are in contact with thin discs having one side curved to fit the inside member and the other side flat to fit a side of the internal square. In the form shown at C, four of the rocker members are used instead of two. These rocker members do not interfere with the universal action and are valuable in that they provide for longer life than the ordinary form of wabble joint as there is ample contact surface between the driving member and the face of the rocker discs and there is also ample surface contact between the driven member and the rounded seats of the rocker discs.

Radius Rods, Torque Members and Control Linkage.—On every chassis there are a number of points where the motion is relatively slight but where the parts are subjected to considerable pressure. Among these may be mentioned the radius rods used with side chain drive cars and the torque members furnished when the bevel or worm drive axles are used. The form of the torque mem-

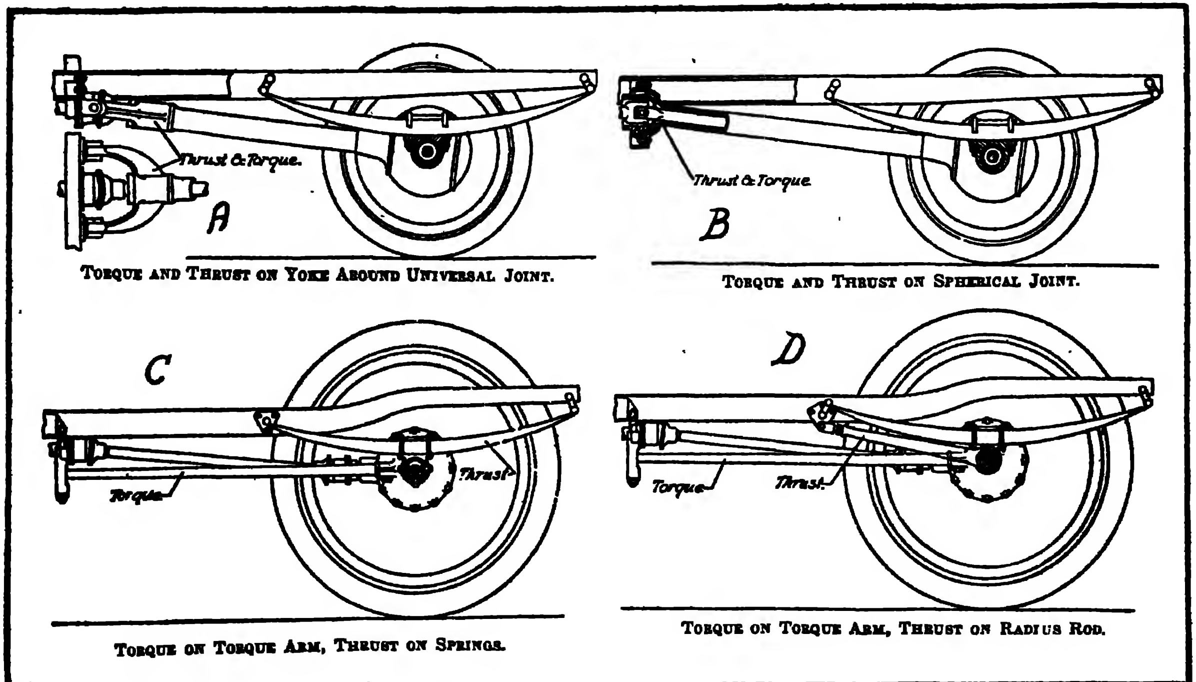


Fig. 366.—Conventional Method of Taking Driving Thrust and Braking and Driving Torque in Modern Automobiles.

ber varies with the system of drive employed and is in turn, dependent upon the preferences of the designer. The reason it is necessary to provide a torque member with a shaft drive axle is that all the time the rear wheels are propelling the vehicle the reaction tends to turn the axle housing and this motion must be resisted by some arrangement that will hold the axle in its proper position. The torque members are also required when the brakes are applied to a car because there is also a tendency for the axle to rotate when the retarding force is applied to stop the wheels from turning. The various common forms of torque members are shown at Fig. 366, these illustrations having been reproduced from the Horseless Age.

The construction shown at A is a common one and is used on a number of cars, some of which, as the Overland, are sold in very large quantities. In this construction, the propeller shaft to which the bevel driving pinion is secured is carried by a long tube securely fastened to the axle at one end and carrying a yoke casting at the other supported by suitable bearings attached to the frame cross member. This yoke is mounted so it swivels on the axle tube, permitting the axle to be higher on one side than the other without stressing the joint, a condition that is often necessary and, in fact, unavoidable when running over rough roads. It is evident that the rear axle is also subjected to an up and down motion, this being due to roughness of the road surfaces. In order to provide for this movement the yoke casting is hinged to the frame cross members. When this construction is followed there are three points where depreciation can exist. The points that will wear soonest are the supporting pins or bolts at the ends of the yoke member that fit the frame. These may wear enough so that there will be appreciable lost motion, which means a rattling sound when the car is operated over any but the smoothest of roads. The remedy for this condition is a simple one, consisting only of replacing the worn pins and bushings in the yoke ends, if the construction permits or of reaming out the holes larger and fitting pins to correspond. The joint where the yoke swivels on the torque tube is usually of larger size and is provided with a generous grease cup. While it is not apt to wear as quickly as the joints of lesser area,

if lubrication has been neglected, it may be found that this joint will fit the housing tube loosely. The remedy is to smooth down the end of the housing tube after the joint is removed in order to secure a round bearing and then to bore out the worn yoke and bush it with bronze or cast iron so that it will be a good fit on the housing tube. Any end play that may exist can be readily taken up by putting a light steel washer or a series of these members between the thrust collar on the housing tube and the yoke casting. In

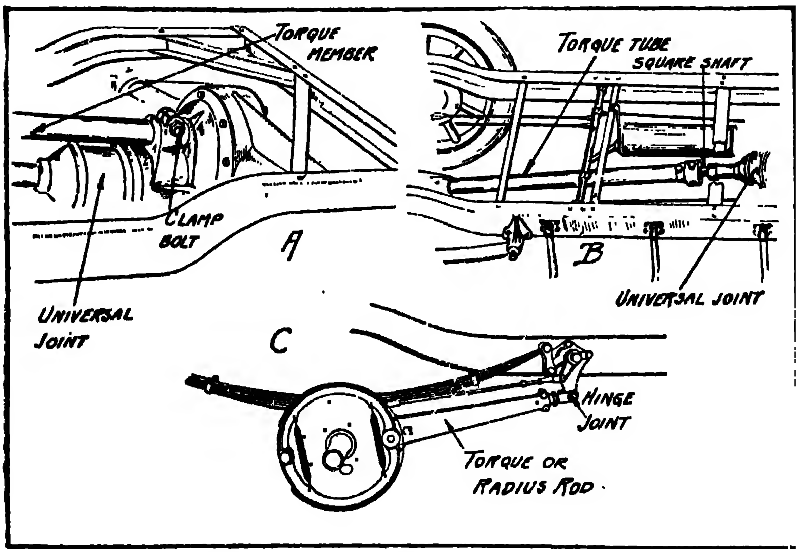


Fig. 367.—Defining Various Forms of Torque Members and Radius Rods.

some cars it is possible to compensate for any end motion by setting up an adjusting nut that keeps the yoke in place.

In the system shown at Fig. 366, B, the push or thrust necessary to move the car, also the torque, is taken on a spherical or ball joint. This construction is used on the Ford automobile and on a number of other more expensive cars. Despite the severe work this type of joint is called upon to perform, it is not subject to undue depreciation, providing that lubrication is not neglected and that proper precautions are taken to keep the grit and dirt incidental

to use from accumulating between the bearing surfaces. If there is any play in this form of joint it often can be compensated for by taking a little metal off the face of the flange of the ball joint cap which permits of bringing it to bear more tightly against the ball on the end of the torque tube.

The system outlined at C is a popular one on many types of cars. In this the driving thrust is taken by the semi-elliptic springs, while the torque is resisted by a special lever securely clamped to the differential housing of the axle at its back end and carrying a small ball end which is suspended in a special shock absorbing fixture carried by the frame cross member. This form is sometimes modified by having short radius rods to take the driving thrust as shown at D, while the braking and driving torque is resisted by a special arm. The flexibility of the special hangers used for supporting the front end of the torque rod shown at C and B, is due to the use of strong coil springs which press against pads having semi-spherical seats to fit the ball at the end of the torque rod. If these springs weaken in use, there may be a certain amount of lost motion between the ball and its seating members which can invariably be corrected by screwing in an adjusting plug carried at the bottom of the tubular spring housing. When radius rods are employed, it is important to test these for side shake when they are supported by the axle or to test the small pins when they are carried by a hinged member secured to the axle and often forming part of the spring pad or seat. Owing to the limited area of the pins that act as hinges at both ends of the radius rods it is not unusual to have these wear enough in a season to demand inspection and attention.

The method of supporting the axle end of a tubular torque member when a two universal joint propeller shaft is used is clearly shown at Fig. 367, A, as will be observed, a retaining member is cast integral with the bevel pinion supporting casting. The tubular torque member is a tight fit in the hole bored into this support and is held firmly in place by tightening the clamp bolts indicated. When overhauling a car it is well to examine this clamping bolt carefully to make sure that the torque rod is securely held. In some cars, where the driving thrust is taken by the springs the

torque is taken by the universal joint. A construction of this kind is shown at Fig. 323, B. The usual construction is to have a square shaft projecting from the torque tube sufficiently long so it will fit the full length of the hub of the universal joint. Up and down movement of the rear axle is compensated for by the sliding of the

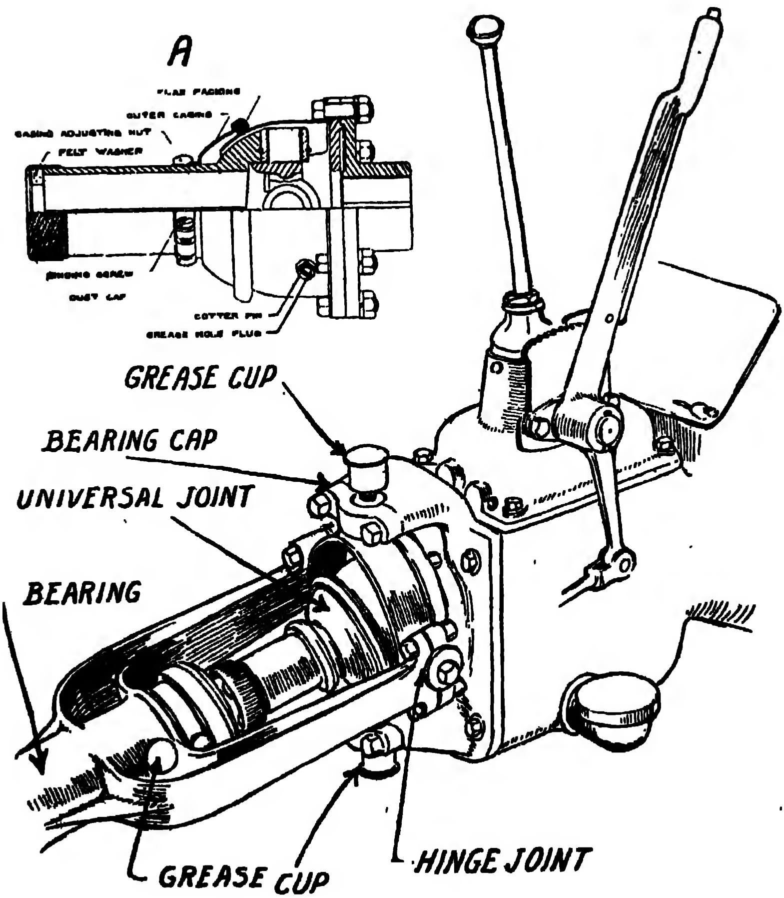


Fig. 368.—Method of Suspending Torque Tube on 1915 Buick Automobiles.

square shaft in the universal joint. This is a point that is very often neglected as regards lubrication, usually because it is inaccessible in most cars. If the square shaft becomes worn there will be considerable lost motion between it and the universal joint. It is often possible to secure a new universal joint member having a smaller square, and as the wear is seldom more than .010 inch it is often possible to save the old shaft by the less expensive procedure of replacing the universal joint member rather than taking the entire rear construction apart to use a new squared shaft. If the universal joint member is a steel drop forging it is possible to heat it up in a forge or brazing flame and then close it down around a square bar of the desired size. The worn end of the square shaft may be dressed down to fit the corresponding portion of the universal joint member. When overhauling a car in which a torque tube is used care should be taken to inspect the point where the torque tube joins the rear axle differential housing to insure that the rivets are tight and there is no motion between the torque tube and its retaining member.

The bearings at the front end of the torque tube are found to be subject to more rapid wear when this construction is followed than when any one of the systems shown at Fig. 366 is used. If adjustment means are provided the bearing depreciation may be taken care of by tightening up the adjustments. If, however, a plain babbitt bearing or bronze bushing is used it will be necessary to replace the defective member with a new one. The end of the torque tube is often provided with a straight roller bearing. If there is much play, the bearing should be examined to see whether the rolls are worn or if the lost motion is due to depreciation of the driving shaft or the roller bearing shell member carried by the torque tube.

The usual arrangement of a radius rod, which may sometimes be arranged in such a way that it takes torque as well as driving thrust is shown at Fig. 367, C. The hinged joint where depreciation can be looked for when overhauling the car is clearly indicated in this illustration. On the Buick 1915 automobiles the end of the torque tube is attached to the gearset in a novel and effective manner. In addition to the usual swinging joint between the

yoke member and the end of the torque tube which takes care of the up and down motion of the wheels, the ends of the yokes are fastened to a ring member having four bearings equidistantly spaced at Fig. 368. Two of these bearings on a horizontal plane are used as a support or hinged joint to permit of up and down movement of the axle. Swaying from side to side is taken care of by the method of supporting the ring at the top and bottom by substantial cast arms, extending from the back end of the gear set. It will be apparent with this construction that depreciation of the supporting pins of the ring may be compensated for to some extent by removing the bearing caps and filing a little off of their faces to permit them to be brought closer to the pins. Of course, it will be necessary to drill the holes out round and ream them to the proper size because the process of compensating for wear will tend to make the holes elliptical, instead of round.

The construction of the universal joint used with this method of installation is clearly shown at the inset A which shows the joint in part section. In addition to the torque and radius rods, all of the various members, such as rod ends on the brake rods and control linkage should be looked over with a view of determining if any wear exists at the bearing pins. As no provision is made for adjustment at these points the only remedy is to drill the holes out larger in both the rod end and its supporting yoke and supply new pins of larger diameter that will fit the holes without lost motion.

Front Wheel Adjustment.—When cup and cone type ball or taper roller bearings are employed, it is necessary to adjust these very carefully to compensate for any lost motion that may exist in the assembly. The condition of the bearings may be ascertained without difficulty when these are used in the wheels by jacking up under the axle to relieve the wheel of the car weight and then by grasping the wheel rim at opposite points and shaking the wheel. Any looseness in the bearings can be detected by the lost motion between wheel hub and spindle. In taking up lost motion when any type of adjustable bearing is employed, considerable judgment must be exercised in screwing up on the adjusting member not to get this up too tightly and impose an injurious end pressure on

the balls or rollers (Fig. 369). An excess pressure that will stress the bearing parts dangerously will not make much difference in the wheel resistance when turned by hand, though when the car weight must be sustained at high speeds or when going around corners, the resistance will be increased materially and bearing endurance reduced in proportion. A safe rule to follow is to take up the wear by screwing in the adjustment nut enough so the "shake" or looseness will be eliminated and yet permit the wheel to "spin" for a few revolutions when given an initial impulse. Many motorists and inexperienced mechanics commit the error of adjusting bearings of the "take up" type too loosely. This is not desirable, any more than fitting parts too closely together is. Always lock the adjustment nut firmly in place when proper adjustment has been secured.

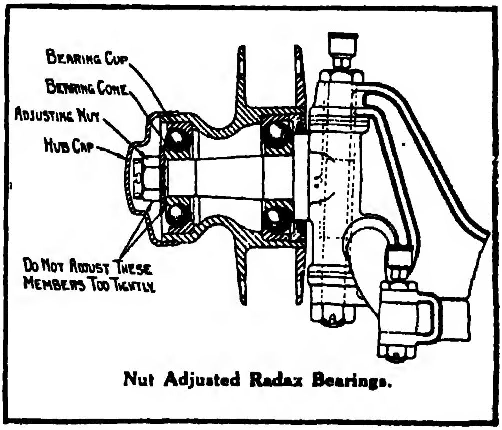


Fig. 369.—Front Hub Showing Nut Adjusted Cup and Cone Type Ball Bearing.

Muffler Faults.—A part of the chassis that is often overlooked in the overhauling and one that has material influence on the power output of the motor is the device used for muffling the sound of the exhaust. The internal construction of mufflers varies widely, some consisting only of simple chambers connected together to form a labyrinth for the gas passage and reduce the noise by breaking up the volume and allowing the gas to expand before it reaches the air to more complicated forms having a large number of baffle plates or partition walls pierced with numerous small holes. The most effective and silent type of muffler is generally the one that will give trouble first. It is important, therefore, to take the muffler apart and clean out all accumulations of soot or burnt oil

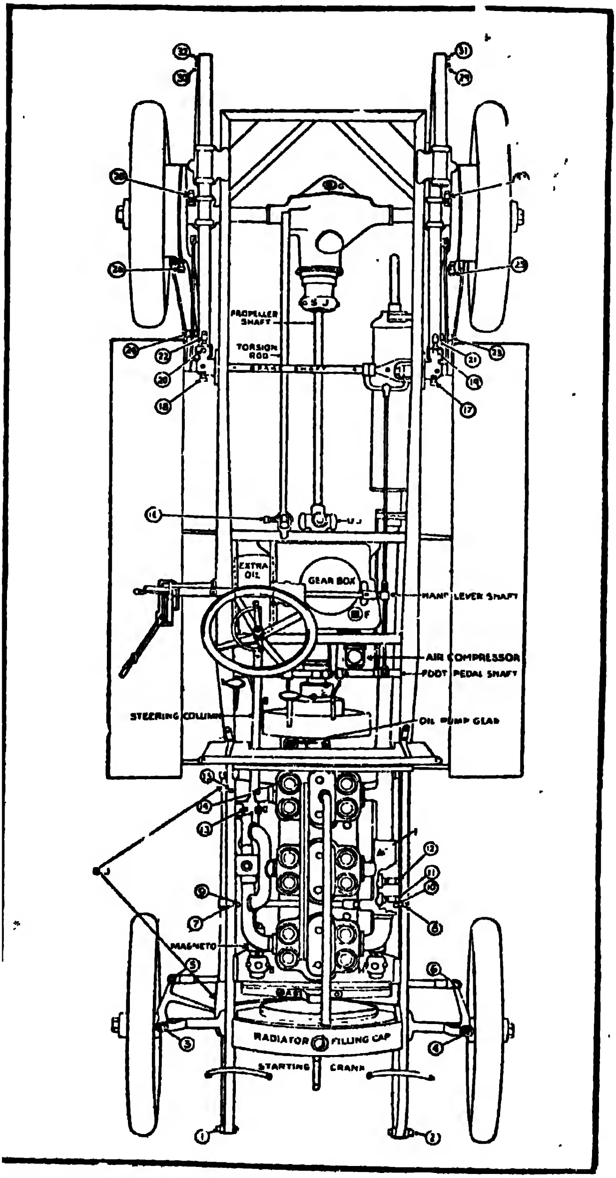


Fig. 370.—Diagram of Locomobile Chassis, Showing Points Demanding Lubrication.

that may clog up the gas passages. Mufflers are easily taken apart, usually being held together by long through bolts in those forms where the muffler consists of a number of cylindrical shells of varying diameter held between cast end plates used to support the shell. Even in forms where a large number of chambers are provided, these being adjacent, the muffler is held together by bolts or by being assembled on a central member usually a continuation of the exhaust pipe. After the muffler is taken apart all carbon and burnt oil residue should be scraped off and all the parts of the muffler thoroughly cleaned with kerosene before reassembling. It is also well to go over all the holes designed to break up the gas with a sharp punch or fine taper reamer to make sure that these have not been reduced to less diameter than they should be by accumulations of burnt oil or carbon.

Chassis Lubrication.—A very important point that is sometimes overlooked after a car has been overhauled is proper lubrication of the chassis. A typical six cylinder chassis of the Locomobile design is outlined at Fig. 370, with all points needing lubrication clearly outlined. Practically all of the chassis parts are lubricated through the medium of grease cups which are indicated by a circle with the numbers in it, the numbers ranging from 1 to 32 inclusive, beginning at the bottom of the diagram and running to the top. It is important to go over all the grease cups when a chassis has been overhauled and make sure that they are filled with a good grade of grease of suitable density which must resist the action of water and contain no acid. Grease cups Nos. 3, 4, 5, 6, 21, 22, 27, and 28 are very important and should receive attention every day that the car is in use. Graphite grease is recommended for these points. In addition to the grease cups there are a number of oiling plugs which are indicated at black squares and a letter. Beginning at the bottom of the diagram, oil plug A should be removed to supply oil to the timing gear. It is said that one and one-half pints of oil are necessary every 500 miles. The magneto drive coupling B should be filled with grease. C is the plug through which grease is introduced to the steering worm gear case. New grease should be supplied when overhauling, then the operator should be cautioned to replenish the supply every 100 miles. D,

indicates the oil opening for filling the oil pump gear casing with grease.

The disc clutch housing is provided with oil plug E. The makers of the car illustrated recommend that this plug be removed at the end of every 1,500 miles and the clutch case turned over until the old oil runs out. The interior of the clutch casing should then be washed carefully with gasoline and refilled with new lubricant. This may be a mixture of one-fourth pint of spindle oil and one-fourth pint of kerosene or a mixture of one-third pint of kerosene and one-sixth pint of three-in-one oil. It is stated that these proportions and quantities are important. The transmission gear case is filled through oil plug F. The gear case should be lubricated with some good quality non-acid grease of about the consistency of vaseline. It is stated that 20½ lbs. of grease are needed to refill an empty transmission case after overhauling. The bevel gear housing at the rear axle is provided with a plug G, through which grease can be introduced to lubricate the bevel drive gearing. It is recommended that this be thoroughly washed out during the overhauling process even if the rear axle is not taken apart. It takes one quart of grease to fill this housing to the proper point. The oil plugs H and I indicate minor driving couplings, which do not require attention very often, inasmuch as the makers advise filling with grease every 5000 miles. It is also necessary to keep the interior of the wheel hubs filled with suitable grease.

Among the minor points that need lubrication are the fan bearings, which may be packed with gear grease at the time of the yearly overhauling. There are a number of minor points indicated by round black dots that are oiled with a hand oil can or syringe by means of oil cups and oil holes. The most important of these are as follows: Starting crank, oil every week. Magneto, few drops every 2000 to 2500 miles. Foot pedal shaft bearings, oil copiously every month. Steering column, squirt plenty of oil through the hole in the steering column every week. Oil also the fixed ends of the spark and gas lever. Hand lever shaft bearings, lubricate every week. Brake shaft bearings, oil about every 2000 miles. Dynamo bearings, forty drops every 100 miles. Steering universal

joints, indicated by the letters B, J, remove the leather boots and pack with good graphite grease every 1000 miles. The universal joints on the propeller shaft, which are indicated by the letters U J and S J, should be inspected, cleaned and packed with grease about once a season. Care should be taken to make sure that the power plant also has the proper grade and quantity of lubricant before the car is permitted to leave the shop. Most cars employ constant level splash systems, which have been previously described, the only precaution is to make sure that the oil is at the proper level in the engine crank case. The strainer screen that filters the oil before it goes into the pump should be cleaned every week, and it is recommended that after 1000 miles road service that the old oil be drained out of the engine base.

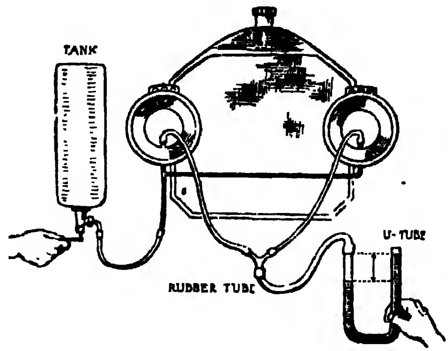


Fig. 371.—Method of Testing Acetylene Gas Piping for Leakage.

Locating Acetylene Gas Leak.—Before the general adoption of electric lighting practically all automobiles were supplied with acetylene gas burning head lights, the gas supply being from a carbide generator, Prest-o-lite or similar tank. In many cases trouble is experienced through leakage of the gas which escapes from minute leaks in the gas line, which usually consists of copper tubes running in the frame channel and connected to the gas tank and lamps with flexible rubber tubes. While the overhauling process is being carried on, it is well to test the pipe lines to see if there are any leaks in order to replace the copper tubes with new ones should they have chafed from contact with a frame member or loose clip or if a seam has opened up with vibration. A very simple method of determining whether there is a leak or not shown at Fig. 371, was described in the Automobile. The apparatus con-

sists of three pieces of rubber tubing, a three way pipe connection and a glass U tube. The burners of the acetylene lights are removed and the ends of the rubber tubes are placed over the projecting pipes as shown in the illustration. The valve on the gas tank should be closed while this is being done. Water is now placed in the U tube but not enough to completely fill it. The needle valve on the gas tank is slowly opened until the water in one arm of the U tube is lifted higher than that in the other because of the gas pressure. The valve is then closed and the water level in the U tube watched. If water drops to the same level in both branches there is a leak. A leak may be found by going over all the pipes with oil or a thick soap-suds solution, taking especial care to cover those portions of the pipes that are resting against the frame members and also all the soldered joints. The escaping gas will cause the soapy solution or the oil to bubble at the point where it escapes.

CHAPTER IX

THE REAR AXLE AND DRIVING SYSTEM

Rear Axle Nomenclature—Semi-Floating Axles—Three-Quarter Floating Axles—Full Floating Types—Taking Rear Axle Apart—Adjusting Bevel Drive Gears—Worm and Spiral Bevel Drive Gears—Two-Speed Axles—Double Reduction Axles—Internal Gear Drive—Four Wheel Drive—Spur and Bevel Gear Differential—Chain Drive Troubles—Trussing Weak Axle Housings—Axle Lubrication—Oil Retaining Means—Types of Axle Bearings—Care and Adjustment of Axle Bearings—Brake Forms and Adjustment.

OWING to the advances that have been made in metallurgy and a more general appreciation of principles of design by engineers, the rear axle is a part of the car that seldom gives trouble and which usually needs attention only when the car is thoroughly overhauled. Very few motor car manufacturers build their own rear axles and most of those used are the product of specialists who make nothing but front and rear axles. The result of this concentration upon one product means that the various details of proportion of parts have received careful attention which has been based on a wide experience. The material best adapted for the various parts have been carefully determined and practically the only condition that interferes with proper rear axle operation, barring occasional accidents, are those due to natural wear. Before describing the method of taking down rear axles it may be well for the reader to become familiar with the different axle types and their method of construction. The designs used vary widely. In some types it is possible to get at all the essential parts in a relatively short time without removing the rear construction from the chassis. In other forms it is necessary to take them completely apart before access may be had to the differential gears or the axle shafts and their supporting bearings.

Rear Axle Nomenclature.—The various types of axles that have been used in automobile construction as defined by the chief engineer of the Weston-Mott Company, one of the largest axle manufacturers in the world, are illustrated at Fig. 372. This shows the four main classes of axles, which are termed semi-floating, three-quarter, seven-eighths and full floating types, these being designated by the letters A, B, C, D, respectively. While the illustrations are self explanatory to one well versed in automobile construction it may be well to describe the various types in detail for the benefit of those who have not had occasion to take all the various types apart. On the semi-floating axle, as shown at A, the entire weight of the car comes upon the axle shafts which also are depended on to transmit the power from the differential gearing to the wheel hubs. It is said that in time this would have a tendency to cause the shafts to crystallize and break unless great care is taken in proportioning the shafts so strong that they will resist the stresses imposed upon them. This type of axle is not generally recognized as the semi-floating form as most engineers call it a non-floating live axle. The reason for this is that the axle shaft does not even partially float as it is held in the hub of one of the differential bevel gears by threaded retention members. In order to be a semi-floating axle it would be necessary to utilize a bearing type at the wheel end that would take end thrust and keep the wheel shaft in place while the part of the axle that projected into the differential would not be held by any threaded nut.

A true semi-floating axle should be of such form that the axle may be readily withdrawn without necessitating the complete disassembly of the rear construction. The axle shown is semi-floating to a degree, however, because the differential gear is carried by bearings which are outside of the differential case bosses instead of bearing directly on the axle shaft, as is the case with light axles of such cars as the Ford. The three-quarter floating axle shown at B is a design in which the axle shaft is subjected only to torsional strains or to a twisting action due to the power applied to drive the car. The wheel bearing is mounted on the axle housing instead of inside of that member as shown at A. This brings the strain due to the weight of the car on the non-rotating axle hous-

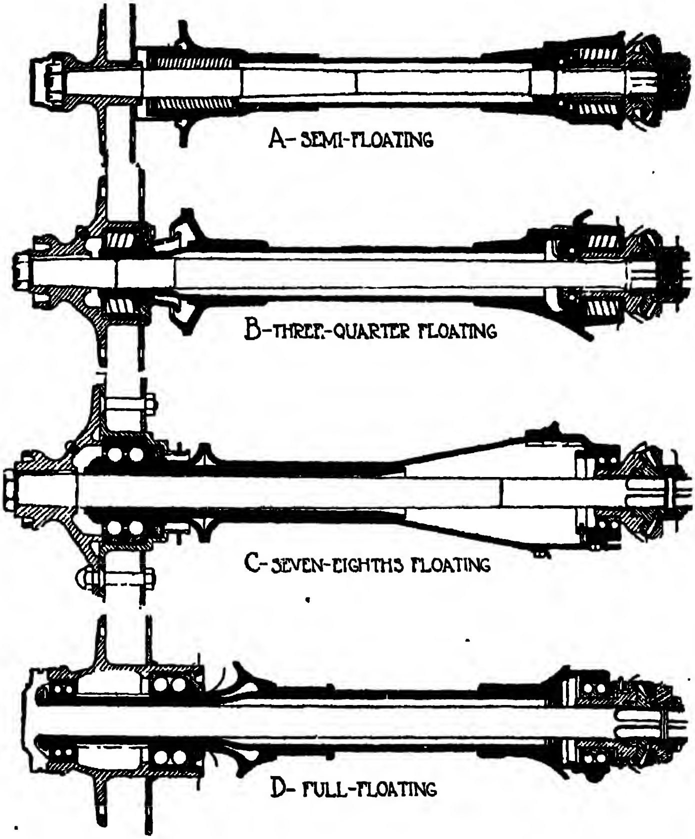


Fig. 372.—Defining Principal Types of Weston-Mott Rear Axle Construction.

ing instead of on the shaft as in the type shown at A. The type shown at C, which is termed the seven-eighths floating by some engineers and which is called a single bearing full floating hub by others, has many of the advantages of the three-quarter floating construction in that the drive axle tends to steady the wheel and also has the advantage of the full-floating type in that the wheel may be removed from the rear construction without taking the

housing apart. The axle shaft may be withdrawn from the differential, which is not possible in the form shown at A and B where the end of the axle is securely retained inside of one of the differential bevel gears by a nut.

The standard full floating type of axle, which is shown at D, does not depend on the driving shaft to steady the wheel, which is held against side movement by spacing the wheel hub bearings on each side of the spoke center line. The advantage of the full-floating type of axle is that the driving shaft may be withdrawn without disturbing the wheels or jacking up the axle and the differential gearing may be removed from the rear construction by partially withdrawing the drive shafts and not requiring jacking up the axle inasmuch as the wheels still support the load.

Semi-Floating Axles.—The difference between the semi-floating and three-quarter floating axles may be readily understood by referring to the sectional views at Fig. 373. The complete assembly of the differential and driving gears with one of the axle shafts of a Weston-Mott three-quarter floating rear axle is shown at A, while a similar sectional view of the Reo axle is shown at B. The semi-floating axle used on some types of Pierce-Arrow cars is shown at Fig. 374. It will be observed that in the Reo construction the axle shaft must transmit the power and also support the portion of the weight of the car that comes on the rear wheel it carries. Beginning with the universal joint on the drive shaft, the power is transmitted through the pinion shaft to the bevel pinion which in turn imparts its motion to the ring gear or master gear riveted to the differential case. When the car is traveling straight ahead the power is transmitted directly to the two differential gears which are fastened to the axle shaft by keys and taper retaining pins and which turn the wheels forced onto the keys on the tapered outer axle end. When the car turns a corner the outer wheel travels faster than the other, suitable compensation for the difference in speed being made by the differential gears and pinions. As will be apparent the pinion shaft is carried by taper roller bearings as is the differential assembly. The axle is supported at the wheel end by a Hyatt, high duty type roller bearing.

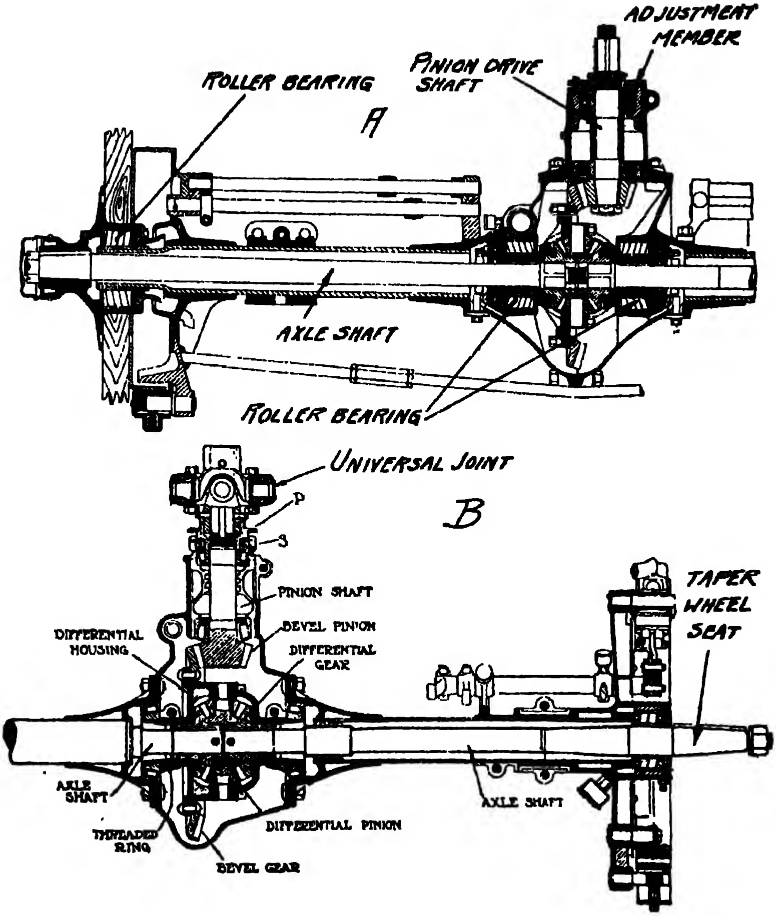


Fig. 373.—Three-Quarter Floating Axle at A, Reo Semi-Floating Axle at B.

There are two adjustments on this axle, one that allows the movement of the differential gearing so the ring gear may be brought into closer mesh with the bevel pinion, when depreciation occurs, or in the initial adjustment when the axle is assembled.

The other is the adjustment of the bevel pinion so this also may be brought into closer relation with the bevel gear. The former is adjusted by removing the rear of the axle housing and turning the threaded rings that bear against the inner races of the tapered roller bearings at each side of the differential gear. It will be apparent that as one bearing adjustment is turned to push the bearing inner race away from the differential that the other must be turned in toward the differential to permit the other bearing inner race to move along its supporting boss. The bevel pinion is adjusted by turning on the sleeve S which moves the pinion shaft and its bearing as a unit. The bearing adjustment is obtained by slowly rotating the adjusting member P as desired. By shifting the big gear endwise, which means that the entire differential must be moved from one side to the other and the driving pinion in and out, it is not difficult to obtain correct alignment of the drive gearing. It is well to have a slight amount of back lash between the teeth of the gears, the amount allowed being about .004 to .008 inch. The position of the driving pinion and gear relative to each other is very important. Noisy gears are the result of the pinion and gear not being in correct mesh. It has been found that if the gears are out of position more than 1 100th inch (.01″) that the gears will be noisy in action. The exact adjustment can best be determined by trial, it being considered more desirable to have some back lash in the gears rather than have them fit too tightly.

In taking a semi-floating axle apart when of the type shown at Fig. 373, B, the first step is to remove it from the chassis, support it by suitable trestles, and then to pull off the wheels from the taper wheel seats. This is done by unscrewing the wheel retaining nut on the threaded axle end and then knocking the wheel off the axle shaft or pulling it off with a properly designed wheel puller, as shown in Chapter II. or in Figs. 353 and 363 herewith. The next step is to release the axle housing tube from the sides of the differential housing by unscrewing the nuts that hold the flanges on the axle tubes from the studs attached to the differential housing. The axle housing may then be easily withdrawn over the axle after the wheel driving keys have been removed from the taper wheel seats. This leaves the differential mechanism in place in the

differential housing with the two axle shafts projecting one on each side. The next step is to unscrew the pinion shaft carrier in order to bring the drive gearing out of mesh. This is done by loosening the clamping nut and unscrewing the sleeve S. After the pinion has been backed off the differential casing may be taken apart and pushed over the axle shafts which will give access to the pins passing through the bevel differential gear. These are knocked out

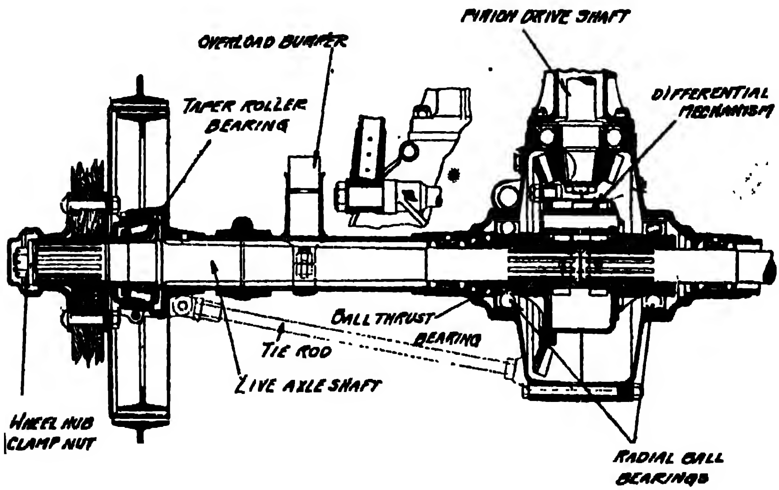


Fig. 374.—Sectional View, Showing Construction of Pierce-Arrow Semi-Floating Axle.

which enables the operator to draw the axle shaft out of the differential assembly. After the two shafts have been withdrawn the differential parts may be easily removed through an opening left by taking off the differential housing cover plate. To take the semi-floating axle shown at Fig. 374 apart it is necessary to remove the wheels and part the differential housing on the center line dividing that member into two symmetrical halves. Before this can be done the pinion drive shaft carrier must be removed and the bolts holding the halves of the differential housing together must be un-

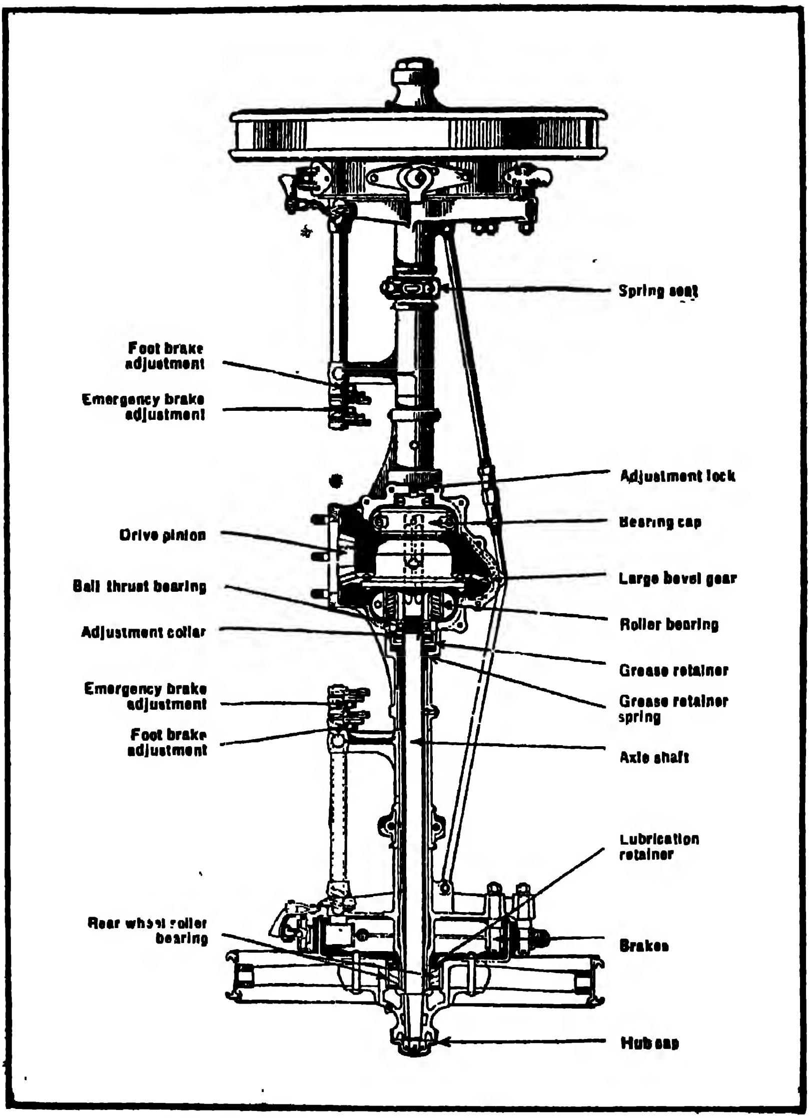


Fig. 375.—Part Sectional View, Showing Construction of Overland Three-Quarter Floating Axle.

screwed. In this construction, half of the differential housing and the live axle shaft housing come off as a unit.

Three-Quarter Floating Axles.—The three-quarter floating axle, such as shown at Fig. 373, A, and Fig. 375, cannot be taken apart until the wheels have been removed from the axle shaft. Here again it is necessary to take the pinion drive shaft off before the differential housing can be split vertically in the axle shown at A. In that shown at Fig. 375, it is not necessary to take the rear construction apart as the differential may be removed from the housing by taking off an exceptionally large cover plate. It is necessary to take the wheels off however, in order to permit the withdrawal of the axle shafts. The gears are meshed in the form shown at 373, A, by a simple adjustment member which moves the pinion drive shaft back and forth in its supporting housing until the proper degree of engagement with the ring gear is obtained. More detailed instructions for adjusting various forms of bevel driving gears will be given in proper sequence.

Full Floating Axle.—The construction of a full floating axle used on some Overland models is shown at Fig. 376. In order to withdraw an axle shaft it is only necessary to unscrew the hub cap and pull the driving end of the shaft out of the slots in the wheel hub into which it fits. The driving end of the axle shaft is provided with a driving clutch member that is intended to fit into depressions milled into the wheel hub. Sometimes the driving clutch will get loose in the wheel hub owing to depreciation of the clutch teeth or the slots in which they engage. If the wear is not too great compensation for the looseness may be made by heating up the ends of the clutch teeth and hammering them out so that they will be even wider than the slots, then filing them to fit. After the axle shafts are withdrawn if one desires to remove the wheel this may be easily accomplished by unscrewing the locking nut that keeps the bearings in place on the axle tube. The wheel may then be withdrawn with its supporting bearings. To remove a differential gear assembly, one must first withdraw the axle shaft completely out of the interior of the differential gearing which is easily accomplished because of the squared ends which fit broached holes in the differential bevel gears and then releasing the differ-

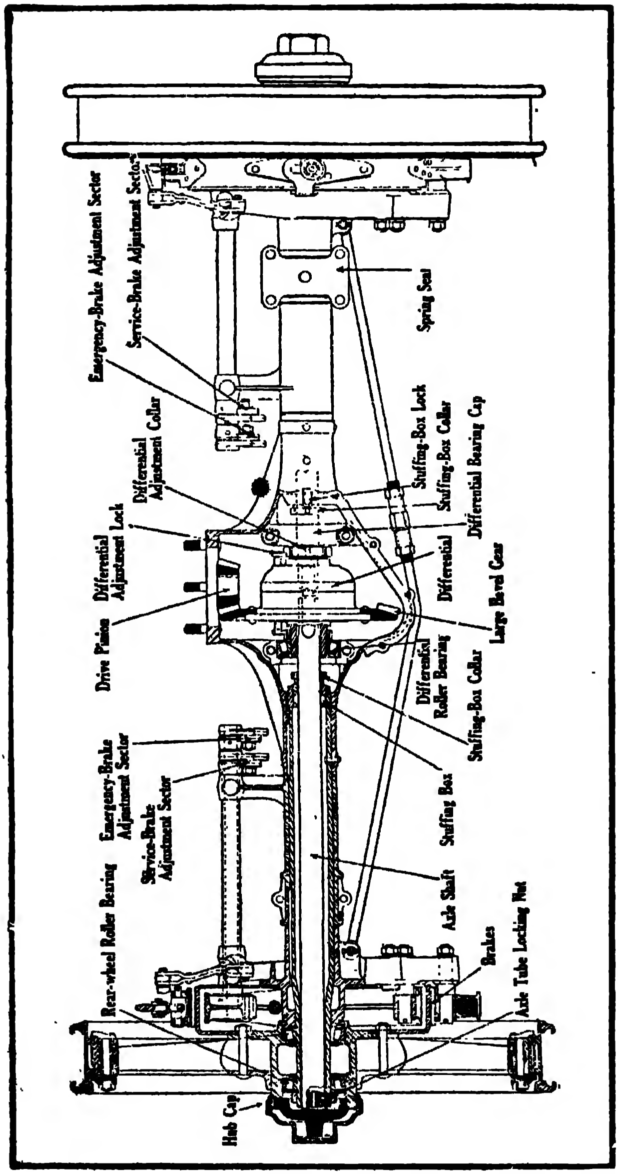


Fig. 376.—Part Sectional View Showing Overland Full Floating Rear Axle.

ential bearing holding caps by unscrewing the retaining nuts or cap screws. The differential may then be removed from the differential housing as a unit with its supporting bearings. In this construction it is not necessary to readjust the bevel gearing because the adjustment need not be disturbed when the differential assembly is removed. This is a marked advantage of the full floating axle design over the semi- and three-quarter floating forms shown at Fig. 373.

Taking Rear Axle Apart.—The parts comprising a typical live axle of the non-floating form are shown at Fig. 377. As will be observed the main portions of the rear construction are three housings. One of these is termed the left half driving gear housing, the other the right half. Attached to these members are the axle tubes which carry the brake assembly at the outer end and a spring seat between the driving gear housing and the brake carrying plate. Each of the axle housings is really comprised of three members, two of these being malleable iron or semi-steel castings joined together by a length of seamless steel tubing to which they are securely attached by riveting and brazing. The propeller shaft which carries the driving pinion is mounted in a separate housing member which has a flange at its lower end by which it may be bolted to the differential housing when the two halves comprising that member are bolted together. The axle drive shafts are shown attached to the differential gears. The parts comprising the differential assembly are shown at the lower right hand corner of the illustration, the brake bands and spring seat are shown at the left hand corner.

In order to understand the method of taking the rear construction apart, the method followed in dismantling the Locomobile axle is shown at Fig. 378. While this member has the advantages of the full floating type in permitting the removal of the wheel drive shaft or wheels when necessary, the differential gearing cannot be removed without taking the differential housing apart. The appearance of the rear construction after the wheel bearings, spring seats, and brake carrying castings have been removed from the live axle housing is shown at A. The first step is to remove the nuts from the studs on the sides of the pinion carrier and the bolts

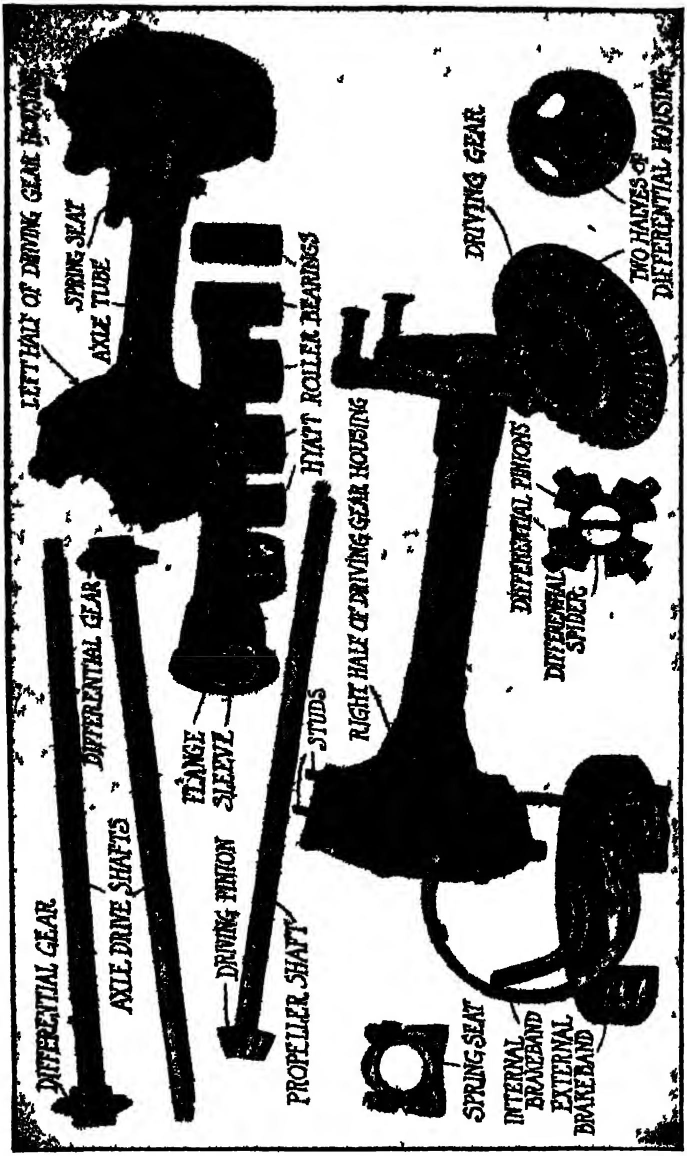


Fig 377.—Parts Comprising Early Buick Non Floating Axle.

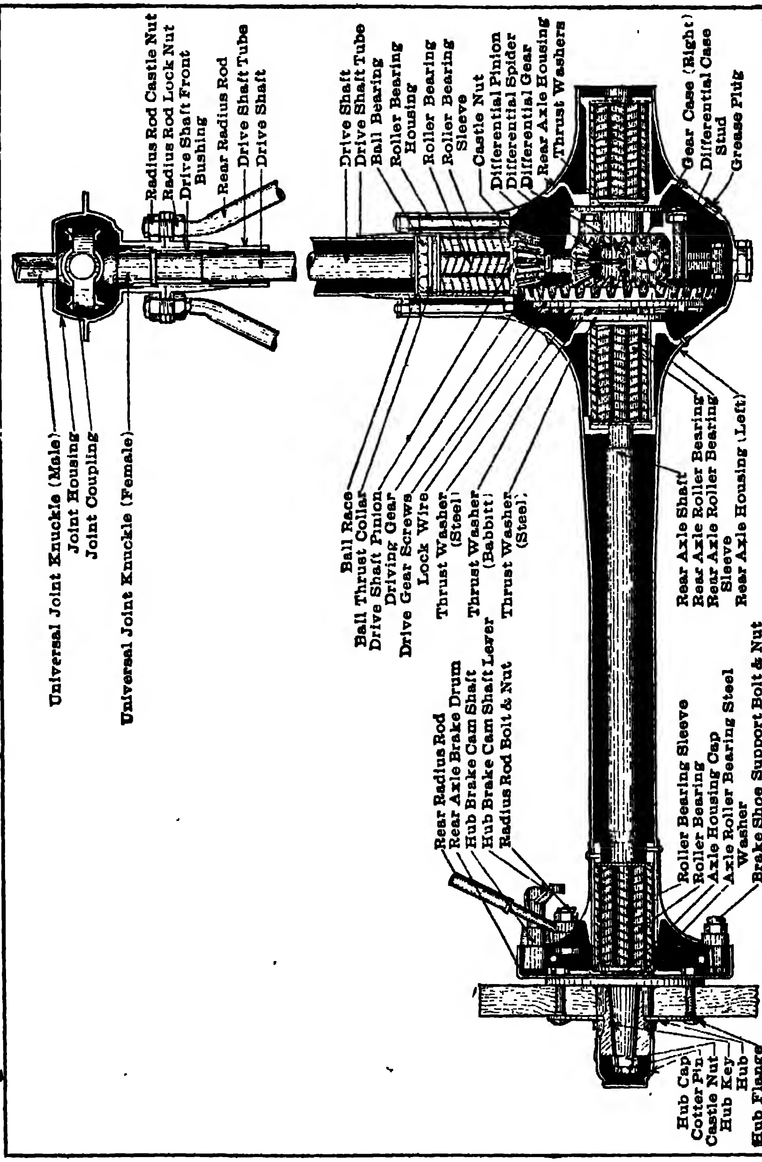


Fig. 377A.—Sectional View of Ford Model T Rear Axle, Showing Driving Gears, Differential, Power Transmission Shafts and Supporting Bearings.

passing through the remainder of the bosses. This permits one to pull the halves of the differential housing apart, exposing the differential gearing as shown at Fig. 378, B. The bevel drive pinion assembly or third member is held in place by three studs in a suitable extension from the differential housing and may be removed from that member as a unit by removing three nuts and withdrawing it from the case.

The parts comprising the differential gear, which is of the bevel gear and pinion type are clearly shown at Fig. 378, C. The differential casing with the ring gear removed is shown at 5. As will be apparent the casing is composed of two halves 1 and 4, these being held together by through bolts passing through the flanges of the case casting. Each flange has four notches of semi-cylindrical form machined therein, these to retain the extension from the differential spider on which the pinions revolve as shown at 2. The spider and pinion assembly in place in one-half of the differential casing is shown at 4. The spider with the bevel pinion and the face gears employed to drive the live axle shafts in the relation they occupy inside of the differential is clearly shown at 3. The points most subject to wear are the bushings in the differential pinions which are usually of bronze and which may be driven out and replaced by new ones and the bushings in the differential case hubs that are employed to support the bevel differential or face gears. If the supporting pins on which the pinions revolve which are part of the differential spider are worn, a new spider member must be substituted for the defective one. But little wear will be found in the teeth of the bevel pinion differential as these are usually a substantial form and because the gearing is thoroughly lubricated at all times. Obviously the process of reassembling the axle is the reverse to that of dismantling it.

Adjusting Bevel Drive Gear.—Bevel drive gearing is supported on two types of bearings, both belonging to the anti-friction class. The type of bearing used for supporting the bevel drive pinion shaft and the differential assembly determines the method of adjustment provided to a large extent. The bevel drive gear assembly shown at Fig. 379, A, is that used on the Hudson Model 37, and is similar in design to that employed on many other cars.

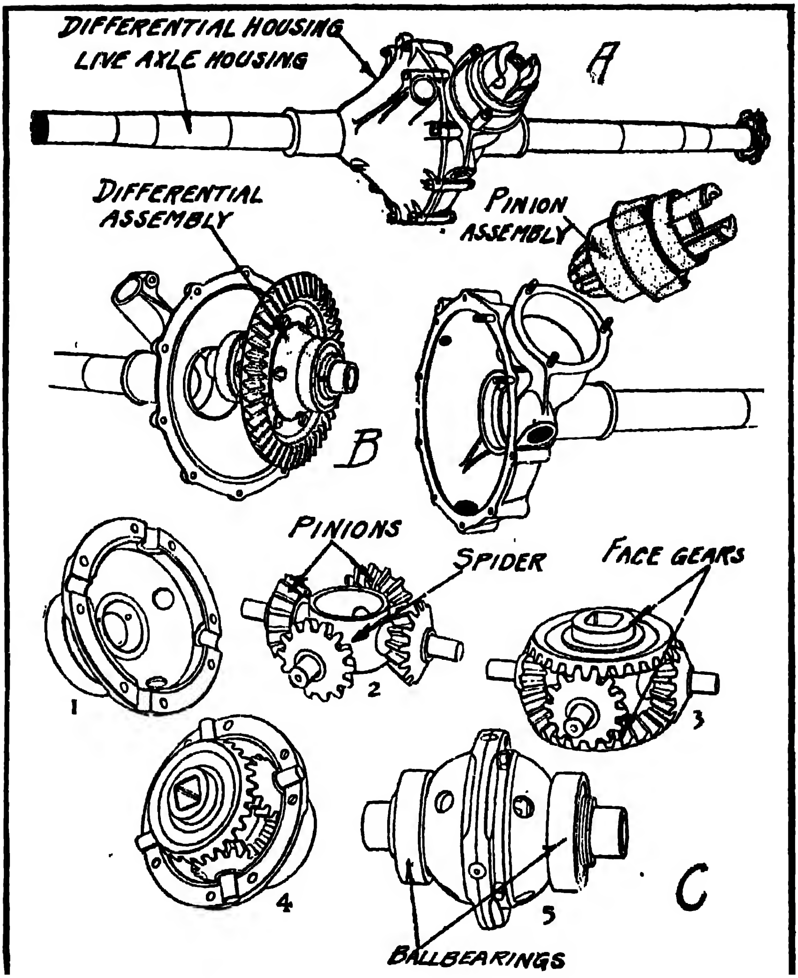


Fig. 378.—Defining Construction of Bevel Pinion Differential Gearing.

In this construction taper roller bearings are used throughout. Following common practice in full floating axles the differential gear and the pinion drive shaft are supported by a common casting in order to obtain correct alignment more easily. The pinion drive shaft is supported by two taper roller bearings, one being placed

immediately back of the drive pinion while the other is used at the upper end of the pinion shaft as a steadying member. The lower bearing is mounted in a threaded adjustment member but the upper bearing seats against a shoulder in the pinion drive shaft housing. In order to mesh the pinion deeper with the ring gear it is necessary to release the adjustment lock that keeps the threaded adjustment from turning and also to back off the adjusting nut for the upper bearing. After the threaded adjustment member has

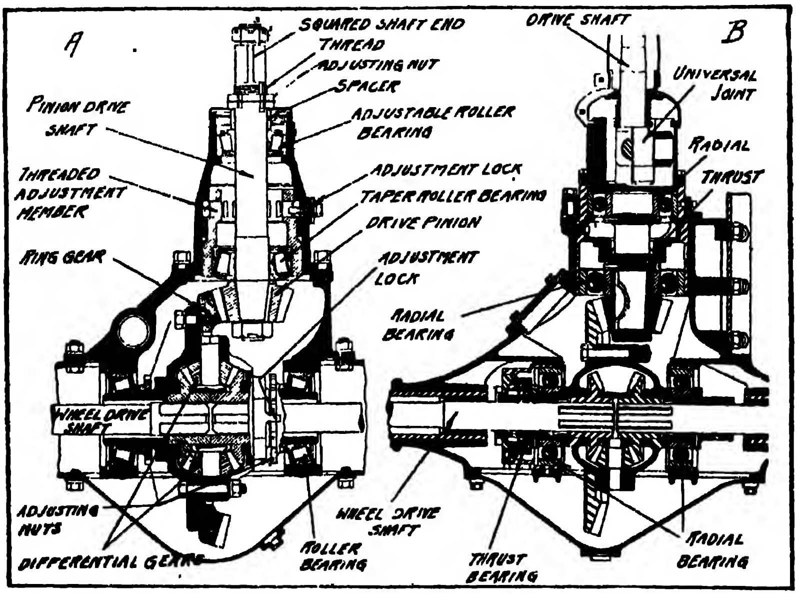


Fig. 379.—Sectional Diagrams of Bevel Drive Gears, Showing Method of Adjusting the Gearing.

been screwed in or out to secure the proper meshing of the ring gear and after it is securely locked in place by screwing the adjustment lock back into one of the slots made to receive it, the upper roller bearings should be carefully adjusted by screwing the adjusting nut against the spacer member, this pulling the inner race of the lower roller bearing firmly against the outer member and in turn seating the outer race firmly in the threaded adjust-

ment member. The adjustment is considered complete when there is absolutely no up and down motion to the pinion drive shaft and when no appreciable effort is needed to revolve it and the differential gear when the wheel drive shafts are pulled clear of the differential gear interior.

The adjustment of the differential gearing and the ring gear is accomplished by threaded adjustment rings or nuts which bear against the inner race of the taper roller bearings employed in supporting the differential. These adjusting nuts are provided with a series of slots by which they may be turned and which also serve to receive the tongue of the adjustment lock member. To move the differential gearing it is necessary to first release the adjustment locks and then to turn one threaded adjustment nut in and the other out until the proper degree of engagement of the gears is secured. For example, in the gearing shown at A, if it is desired to mesh the ring gear more deeply with the drive pinion the adjustment on the right would be slacked off or screwed in toward the differential a certain number of turns, or such portion of a revolution as would be necessary to bring the gears closer together while the adjusting nut on the left is screwed away from the differential the same number of turns in order to keep the roller bearings on both sides in proper relation. There should be absolutely no back lash in the taper roller bearings nor lateral movement of the differential gear assembly. At the same time the gearing should be turned without appreciable effort when the pinion drive shaft is rotated by hand.

The sectional view of the bevel drive gearing of the 1914 Locomobile is shown at Fig. 379, B. This is similar in construction to that previously described except that ball bearings are used instead of the taper roller form. The pinion shaft assembly is carried by two single row radial bearings and one ball thrust washer, the whole being mounted in a carrier member which may be screwed in or out of the housing to secure proper gear engagement. The differential gearing is not adjustable sideways as it is believed that the necessary adjustments can be made by moving the pinion shaft carrier in and out of the differential housing. It will be observed that the ring gear side of the differential is supported by a radial

bearing and a ball thrust bearing. This is because the action of the inclined bevel gear teeth produces a certain end thrust which tends to move the differential assembly to the left, this end thrust being resisted by the ball bearing especially fitted for that purpose. A radial bearing is used on the right hand side of the differential casing, this carrying a radial load only. Whenever an adjustment has been altered it is important to make sure and lock it firmly into its new position by the means provided for that purpose. In most cases these are readily apparent upon inspection.

The adjustment of the large bevel gear in the Overland rear axle shown at Fig. 375, requires careful attention to details to accomplish successfully. Take the cover from the differential housing by removing the cap screws by which it is retained. Remove the thrust bearing adjustment lock on the side toward which the differential is to be moved with a screw driver and turn the adjusting cup of the thrust bearing in the same direction. These various parts are plainly identified by suitable lettering on the illustration. Next loosen the two screws which hold the split differential adjusting collar until that member may be turned in the desired direction. Moving the collar on one side of the differential makes it necessary to adjust the one on the opposite side accordingly, both axle ends having right hand threads. When the proper meshing of the gears is obtained, tighten both collars and follow this by bringing the thrust bearings close to the adjusting collars. Be sure to tighten all screws and to replace the small locks which keep the cups from turning after adjustment has been made.

To remove the axle shafts it is necessary to loosen the screws of the differential adjusting collar until the threaded portions of the shaft may be withdrawn through the collar. To remove the differential gear it is necessary to withdraw the axle shafts first, then to remove the roller bearing retention caps. The differential may then be lifted out of its housing. When reassembling, it is imperative to mesh the bevel gears correctly and to adjust the ball thrust bearings properly, taking care not to get these too tight against the differential adjustment collars. If the axle leaks oil it is necessary to renew the grease retaining felt washer.

All differentials and driving gear assemblies are not capable of

being adjusted as in some axles one depends more on a close fitting up of parts when the axle is first constructed. Two types of differentials that cannot be adjusted to change the relation of the driving gearing are shown at Fig. 380, B and C. That shown at B has been used on a number of Pierce-Arrow models and as will be

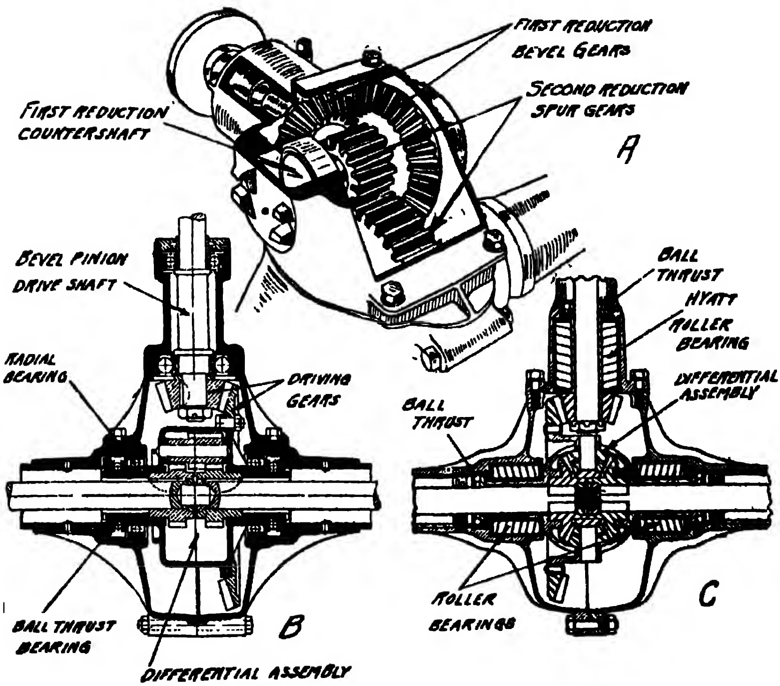


Fig. 380.—Showing Construction of Non-Adjustable Bevel Gear Drive Units.

apparent the differential housing is divided vertically in the center and no provision is made for adjusting the ball thrust bearing mounted at either side of the differential case. As but little depreciation will exist in a well designed and properly constructed rear axle it is believed that any depreciation can best be remedied by the substitution of new parts for those that have become worn.

The same is true of the assembly shown at C. In this roller bearings are used to support the differential while ball thrust bearings are depended on to take the end thrust on the wheels as well as that produced by the bevel gears. When these axles are taken apart there is only one way in which they can be reassembled as far as replacing the bearings is concerned, although on many types in which symmetrical axle housings are used it is possible to replace the differential assembly so the master gear will be on the wrong side of the pinion. This will result in the rear wheels turning backward when the forward speed ratios are engaged and of turning forward when the reverse gears are in mesh in the transmission. The bevel gear in the assembly shown at C, is on the right side of the pinion for engines as ordinarily constructed, that is, those turning clockwise. In the assembly shown at B, the differential is placed in such a way that if used with an engine turning clockwise the drive will be reversed when the forward ratios of the gearset are engaged. Care should always be taken when an axle is dismantled to notice the relation of the parts before they are taken out to make sure that they are replaced correctly.

In some cases double reduction gearing is used in the rear axle. This is employed in gasoline commercial vehicles and some electric pleasure cars. The rear construction shown at Fig. 380, is that used on the Autocar trucks and combines spur and bevel gears in such a manner that two reductions of speed are obtained in the axle housing itself. On the end of the drive shaft a bevel pinion is carried which meshes with the ring gear which instead of being attached directly to the differential as in the conventional construction, is employed to turn a countershaft on which a spur pinion is mounted. A spur gear is secured to the differential and meshes with the spur pinion on the cross shaft. A primary reduction is obtained between the bevel pinion and gear, the second reduction of speed being secured between the small spur pinion on the cross shaft and the large spur gear attached to the differential. A differential cross is carried in the interior of the differential case and the bevel pinions of the differential revolve upon the arms of this cross. The gears in the interior of the differential are carried in the differential case by means of bronze bushing and the hole through

the gears is broached to fit the inner ends of the wheel driving axle. It is not difficult to remove the differential assembly from the axle as the top portion carrying the bevel drive gears in the first reduction countershaft may be lifted off of the differential housing after the driving shaft is disconnected, and then the differential gear assembly can be lifted out of the housing member in the same manner as described for the full floating single reduction axles.

Worm and Spiral Bevel Drive.—In an endeavor to secure quiet operation while running, which is not always possible with the

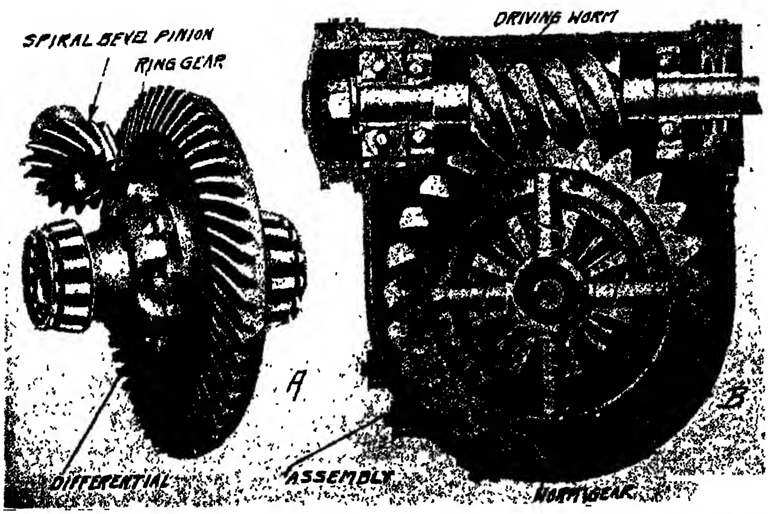


Fig. 381.—Outlining Construction of Spiral Bevel Drive Gearing at A and Worm Drive Gearing at B.

straight type of bevel gears, a number of automobile designers have adopted the spiral bevel drive gear which is shown at Fig. 381, A, for pleasure car service and the worm gearing shown at B for commercial vehicles. The advantages of the spiral bevel gear are mainly due to the shape of the teeth which roll into engagement more smoothly than the ordinary form of bevel gears. It is stated that with spiral bevel driving gears the gears need not be meshed as accurately as with the straight gears to secure quiet operation.

The same rules that have been previously given for adjusting straight bevel gears apply just as well to the spiral bevel form.

The worm drive axle as usually constructed is so devised that the initial adjustment provided at the factory by careful machining of parts is never disturbed except through wear. If an adjustment is provided on either side of the differential assembly to which the worm gear is fastened. great care must be taken to line up the gearing in such a way that the center line of the driving worm will coincide accurately with that of the worm gear. In taking down a worm drive axle it is necessary to examine the condition of the ball thrust bearing carefully and to make sure that all parts of this member are clean and in good condition. Very large thrust loads are imposed on the supporting bearings of both worm and worm gears so it is important to always adjust these members so that they can take this thrust load and make sure that the single row radial bearings are not subjected to any end thrust. In the best designs of worm drive axles, the worm gearing is carried by a supporting casting which permits of careful alignment before assembling into the axle housing. The worm gear is usually made of hard bronze while the driving worm is of hardened steel. If lubrication has been neglected or if oil of insufficient body has been used, most of the wear will be found on the teeth of the worm gears. There is no compensation possible for reduction in tooth size other than replacing the worn gear with a new one.

Two Speed Axles.—The repairman is apt to encounter rear axles in which two sets of bevel driving gears are used in order to provide two speeds in the axle itself. That shown at Fig. 382, A, was used on 1914 Cadillac cars while that shown at B is the Austin design and has been used for several years on cars of that make. The construction of the Cadillac two speed rear axle, which was made by the Timken Axle Company, is shown at A. The power is transmitted from the drive shaft of the gear set in the usual manner through either of the bevel gear sets A and B or C and D. With the inner set the ratio is 3.66 to 1 on the high gear while with the outer sets the ratio is 2.5 to 1. The two large bevel gears B and C are riveted to the differential gear housing, though one of the pinions A and D that drive them is always loose on the drive shaft.

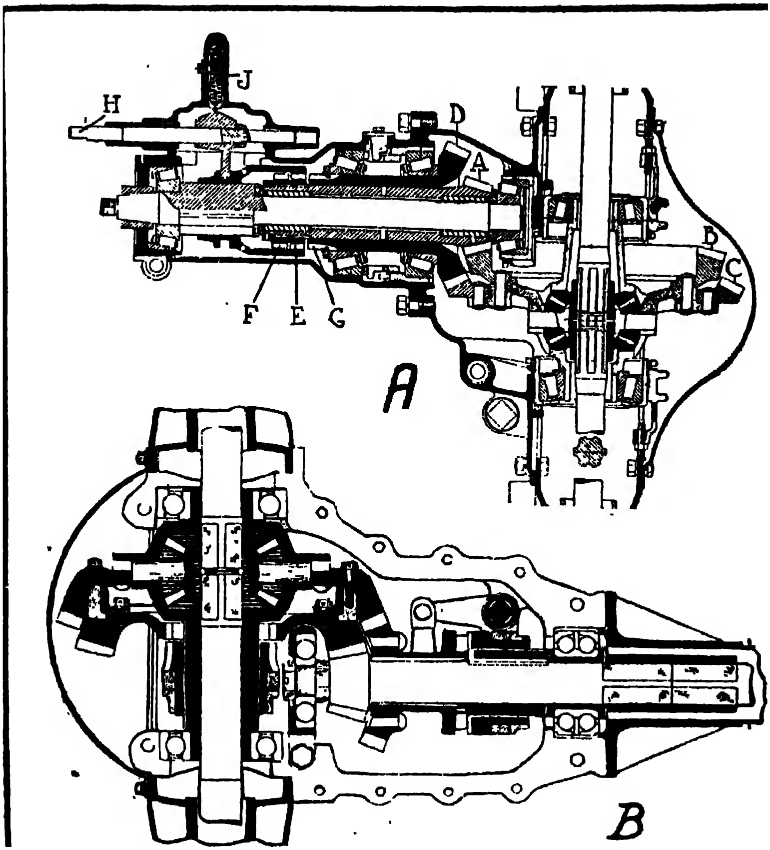


Fig. 382.—Examples of Two Speed Rear Axle. A—Cadillac 1914. B—The Austin Construction.

Pinion A is carried by roller bearings while pinion B revolves on Timken roller bearings carried by the casing. A sliding dog clutch member E may be employed to clutch either clutch teeth F which drive bevel pinion A or clutch teeth G which drive bevel pinion D. The sliding clutch is operated by the shifting rod H which is magnetically operated and which is locked in either position by the spring J.

The construction of the Austin axle is somewhat different as in this design two sets of clutches are used, one working on the differential, while the other works on the drive shaft. To drive the car with the larger bevel gears the clutch member on the drive shaft is engaged with the dog clutch attached to the sleeve to which the larger bevel driving pinion is attached. Movement of this clutch simultaneously operates that on the differential case extension so the smaller of the bevel ring gears is disengaged. The drive is then through the large bevel pinion and the large ring gear. To obtain the other gear ratio the clutch on the driving shaft is shifted out of engagement while that on the differential case is shifted into place inside of the smaller of the two bevel driving gears. When this is done the small driving gear is coupled to the differential casings by means of the clutch and is driven from the small bevel pinion on the drive shaft. The large bevel gear which is attached to the differential revolves the bevel pinion with which it meshes idly on the driving shaft. The clutches are interconnected by a lever so that one cannot be engaged without releasing the other.

Obviously there are more parts to wear in the two speed axle and failure to drive on either gear ratio must be due to faulty clutch action. In view of what has been said previously about bevel gear adjustment there should be no trouble experienced in securing proper driving engagement of the bevel gearing when adjustments are provided for this purpose. In the Cadillac design the entire differential assembly may be moved over just as in a single speed axle. In the Austin design shown at B, no provision is made for gear adjustment other than that initially provided when the gearing was assembled at the factory. In the Austin axle plain bearings are used inside of the sleeve carrying the largest bevel drive pinion and also to support the smaller of the bevel drive gears. Any depreciation of the plain bearing surfaces will result in noisy action and can only be prevented by replacing the worn bushings with new.

Double Reduction Axles.—In commercial vehicles it is desirable to use a lower driving ratio than could be conveniently provided by a single pair of bevel gears, and yet it is desirable to retain the advantages of the full floating type of axle. A typical

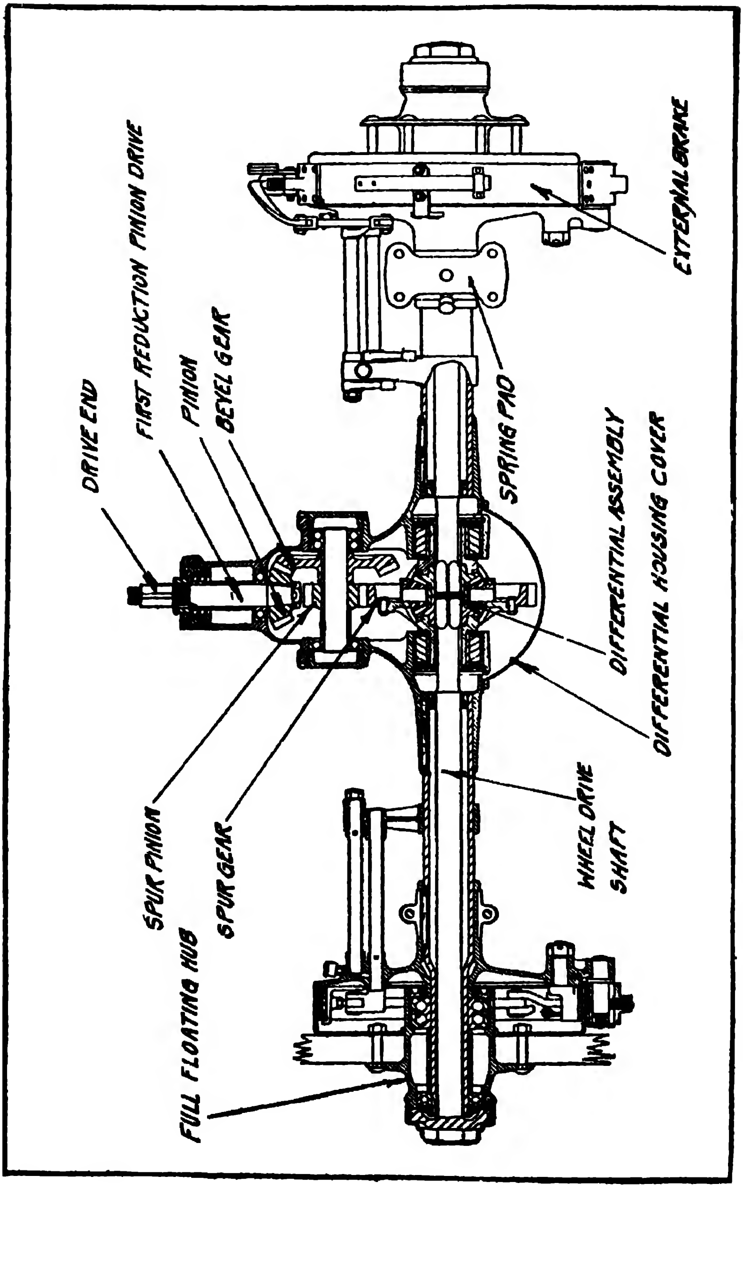


Fig. 383.—Sectional View of Weston-Mott Double Reduction Full Floating Rear Axle.

double reduction axle of Weston-Mott design is shown at Fig. 383. In general construction and arrangement of gears the axle is very similar to that used on the Autocar and previously described. This is a built up construction consisting of cast malleable iron differential housings and heavy steel tubes swaged down at their outer ends to take the bearings on which the wheels are mounted. The differential is mounted on high duty roller bearings having only plain thrust washers to hold it in place because there is no side thrust from the spur driving gear. The differential assembly is driven by a large spur gear meshing with a pinion on a short countershaft in front of the differential. This shaft is driven by bevel gears from the propeller shaft in the usual way. The housing is split vertically through the center line of the short shaft and has a pressed steel inspection cover at the rear. The parts may be examined by removing this cover. As is true of all full floating axles the axle shafts may be withdrawn by merely removing the hub caps serving to keep them in place.

Another form of double reduction axle is shown at Fig. 384. This is known as the internal gear drive type and is very satisfactory in commercial applications. The main feature of these axles is the combination of a non-revolving load carrying member with a jack shaft similar in construction to a live rear axle which drives the rear wheels through the medium of small spur pinions meshing with large internal ring gears. As shown in the drawing the carrying member is an I section drop forging upon which the wheels are mounted. There is an opening in the center of the forging in which the central housing member carrying the differential assembly and driving pinion is securely bolted. The power transmission member is located at the rear of the supporting axle. The construction is such that the differential assembly may be removed without taking the entire axle apart, though the wheels must be taken off of the spindle to permit the withdrawal of the pinion drive shafts. The method of adjusting the bevel pinion is the same as has been previously described in which the entire pinion assembly including the drive shaft and supporting bearings may be moved in or out to mesh with the differential ring gears. To adjust the gears to one side or the other the lock members carried at the rear end of the axle and

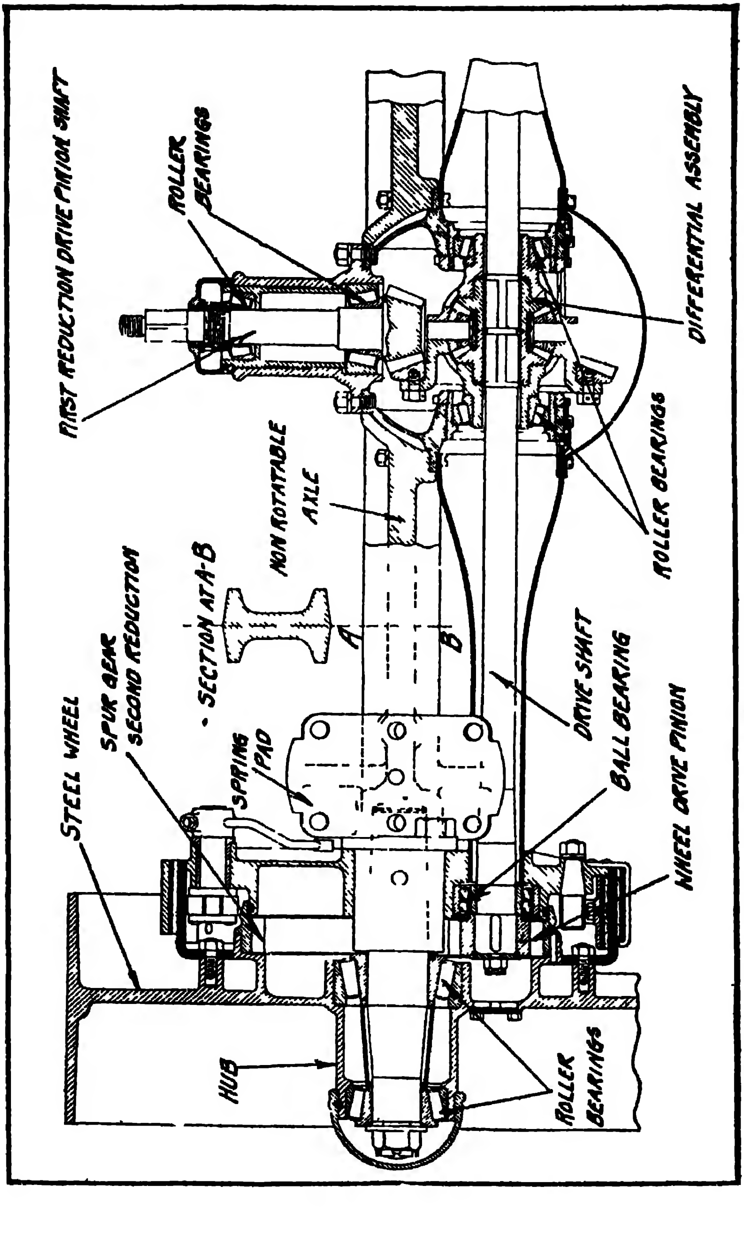


Fig. 384.—Part Sectional View Showing Construction of Internal Gear Drive Rear Axle.

which are removed by taking off the pressed steel cover must first be released. The taper roller bearings are carried in cages or housings provided with threaded adjusting nuts which may be used to draw the housing of the bearing the way it is desired to adjust the ring gear. Obviously it will be necessary to loosen one of the nuts

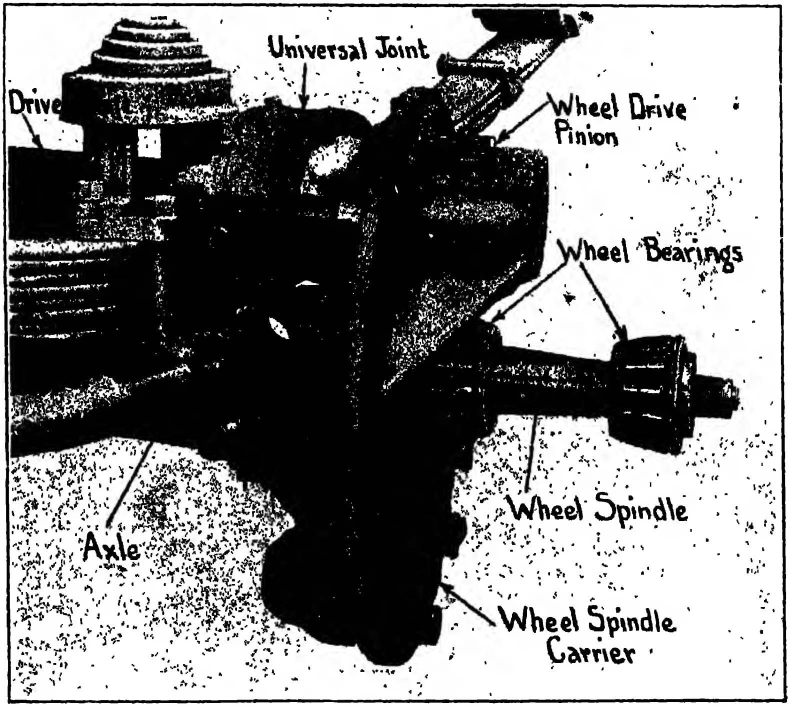


Fig. 385.—Showing Arrangement of Mobile Wheel Spindle Used on Jeffery Four Wheel Drive and Steer Truck.

by moving it toward the differential assembly the same number of turns that the other adjustment member is screwed away from the assembly when adjusting gears.

Four Wheel Drive Systems.—There is a growing appreciation of the value of having all four wheels of commercial vehicles combine directive and tractive functions, especially if these are to be employed for towing trailers as well as carrying a load on their

own platform. One of the leading exponents of the four wheel drive system in this country is the Jeffery Company, the chief peculiarity in its design being in the construction of the axles. Both front and rear axles are the same in construction, the general design being shown at Fig. 385. The wheel carrying spindle is attached to a member that may be moved back and forth on the axle end for steering the same as the front wheel spindle of any car is. The method of imparting the motion of the driving shaft to the wheel even when that member is at an angle for steering is simple. A differential assembly is carried by the non-rotatable axle forging, the drive to the wheel being through a drive shaft and universal joint attached to the wheel drive pinion. The construction is similar to that of the internal gear drive previously described, except that a universal joint is interposed in the driving shaft to permit the wheel drive pinion to assume the same angle as the wheel spindle carrier without excessive loss of power.

Spur and Bevel Gear Differential.—Differential gearing is of two main patterns, that shown at Fig. 378, C, being termed "bevel gear type" because only bevel gears and pinions are employed while that outlined at Fig. 386 is known as a "spur gear differential" because gears of the spur form only are used in providing differences of wheel speed when turning corners. The differential is one part of the automobile that seldom gives trouble, the bevel pinion form being stronger as a rule and less liable to breakage than that using spur pinions. If the differential is at fault, trouble will be experienced in steering the car around corners if the parts are wedged together so that none of the gears can turn, whereas if the teeth are broken or sheared off it will be impossible to drive the car. Before the advent of high grade alloy steels and before the art of heat treatment was as well understood as it is at the present time, differential gears of the spur pinion type were apt to become inoperative through the gears cracking or the teeth stripping. At the present time these troubles are not apt to occur because high grade steels are used in differential constructions. When testing o see if the differential is in good condition it is necessary to jack ıp the rear axle till the wheels are clear of the ground. One wheel hould be turned by hand and if the other turns in the same di-

rection and cannot be prevented from rotating except by the exertion of considerable effort to restrain its movements, it is a sign that the differential gear is not functioning properly and that it is stiff in action. On a number of early makes of cars; especially cheap ones, the bevel differential gears were held on the wheel drive axles by pins which were apt to shear off after being in use for some time. This will permit the gear to revolve independently of the shaft and not drive the wheel. Another fault was shearing of the retaining bolts or rivets that held the differential assembly and the ring gear together. This would permit the driving gear to revolve without turning the differential case.

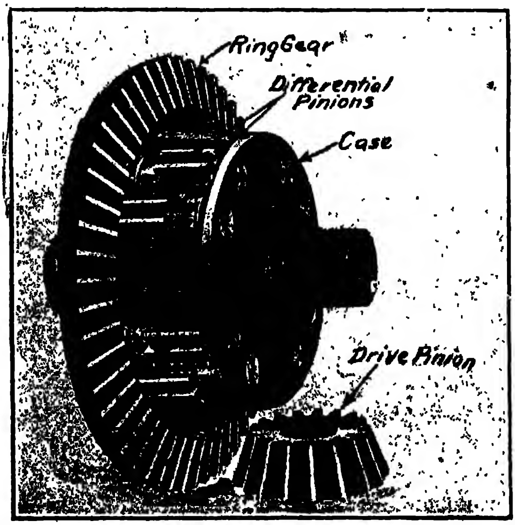


Fig. 386.—Spur Gear Differential.

In most bevel differentials and in all spur forms the small pinions are bushed where they revolve on a supporting pin. After the differential has been in use for a period, and especially when lubrication has been neglected, these bronze bushings may become worn enough so the bevel pinions will be loose on their supporting pins in one case and the spur pinions have lost motion on their supporting axles in the other. As these bushings are not adjustable it is necessary to drive out the old ones and to force the new ones to compensate for this depreciation. The gears attached to the wheel drive axle are employed in a number of cases to support the drive shafts rotating with them in the differential casings. Any lost motion in the bushing surrounding the face gear hub must be taken care of by forcing in new bushings in the differential case bosses. The method of taking a bevel differential apart is clearly

outlined at Fig. 378, C, as is also the relation of the various parts in different stages of assembly. The housing of the average spur pinion differential may be taken apart by unscrewing the pins on which the differential pinions revolve as these also serve as retention members to keep the two members comprising the differential case together.

Chain Drive Troubles.—There are very few chain driven pleasure cars in use at the present time, these generally being models five or six years old. Chain drive is still used extensively on commercial vehicles, however, so it will be necessary to give some instruction for the care and adjustment of chains. Most of the troubles in chain drive are due to worn driving chains or sprockets. The reason for this depreciation is that chain drives, for the most part, are run without any protective casing and grit and dirt collect between the chains and sprockets and in the bearing surfaces of the chain itself, and if not removed by frequent cleaning of the chain it will rapidly grind away the sprocket teeth and cause the chain to become very loose. A typical chain drive system is shown at Fig. 387. The wheels revolve on a non-rotatable axle, being carried in most cases by some form of anti-friction bearings. Power is transmitted from small sprockets carried by a jack shaft supported by the chassis frame to the larger rear sprockets usually secured to the brake drums by means of some form of steel link chain, the roller chain being the form most generally applied. If the sprocket teeth are worn hook shape, it is necessary to replace the sprocket with new ones. If the chain is too loose, so that it "whips" when in service, the radius rods that are fastened to the axle at one end and the jack shaft at the other may be lengthened by the adjustment means provided to increase the center distances between the driving and driven sprockets. Tightening chains must be done with judgment as it is more undesirable to run them too tight than it is too loose. When a chain has been tightened to a sufficient degree there should still be a small amount of slack which will permit the chain to drop at its lower side as shown at Fig. 387.

A driving chain is tested for wear by bending it sideways to feel the looseness between the link pins and bushings. After considerable wear has taken place on each of the bearings of the chain

links the chain will have lengthened out of pitch and should not be run as it will produce rapid wear of the sprockets. After a chain is worn it is apt to break when a load is suddenly applied, or when the engine is called upon to exert its maximum power as in climbing grades. The two forms of chains that have been generally applied for driving an automobile are the roller chain as shown at Fig. 388, B, and the silent chain shown at Fig. 389. The

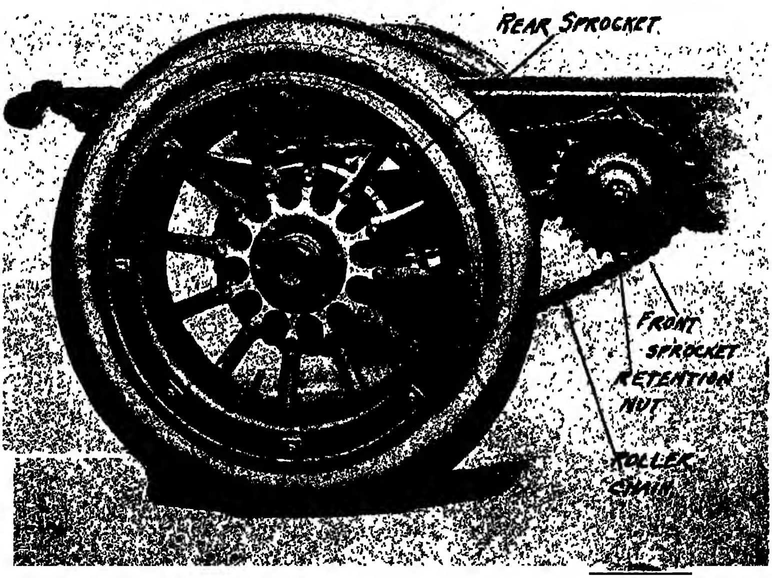


Fig. 387.—Practical Application of Side Chain Drive.

block chain, which is shown at Fig. 388, A, has been seldom applied except on very early forms of automobiles. The roller chain is made in two main types, the quick detachable which is shown at B, and the riveted type as shown at C. With the riveted type new links can be replaced only by driving out the rivets with a steel drift after the ends have been ground off to permit driving the rivet out of the side plate.

Quick detachable types offer the advantage of being taken apart at any point by removing a simple lock member which may be in

the form of a stamped plate, as shown at B or a split pin passing through the end of the rivet as shown at D. Even the riveted types of chains are joined together by a quick detachable link member which is called "a master link" to permit taking the chain off of

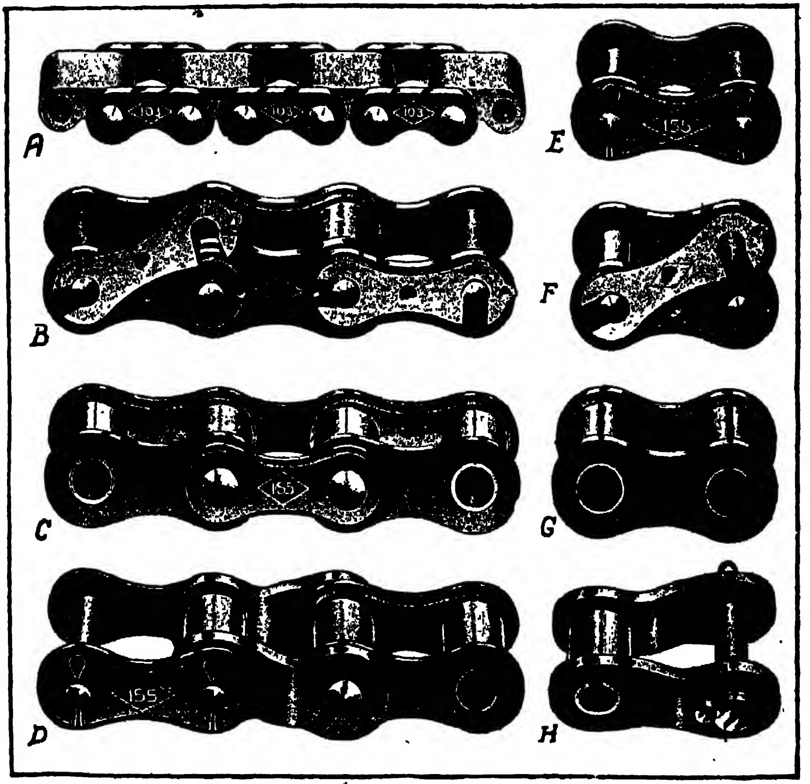


Fig. 388.—Showing Forms of Driving Chains and Repair Links for the Same.

the sprocket without having to drive out retaining rivets. The chain repair links are made in a number of types, those shown at E and F, Fig. 388, consisting of two side plates with the rivets or pins that form a bearing for the roller link shown at G. When it is not possible to shorten a chain by removing a roller link as at G, and one of the pin-carrying links as at E and F, a special

off-set link shown at II is provided. As will be apparent this will join one of the side plate links with one of the roller carrying links.

The method of taking the chain apart shown at B may be readily understood. The ends of the roll carrying pin are provided with annular grooves machined around them. The locking member is a stamped steel plate which is pushed over the pin and which has a horizontal slot in one end that is slightly less in width than the diameter of the rivet pin, and which therefore cannot come off of the pin when it is forced into the groove at the end of the pin.

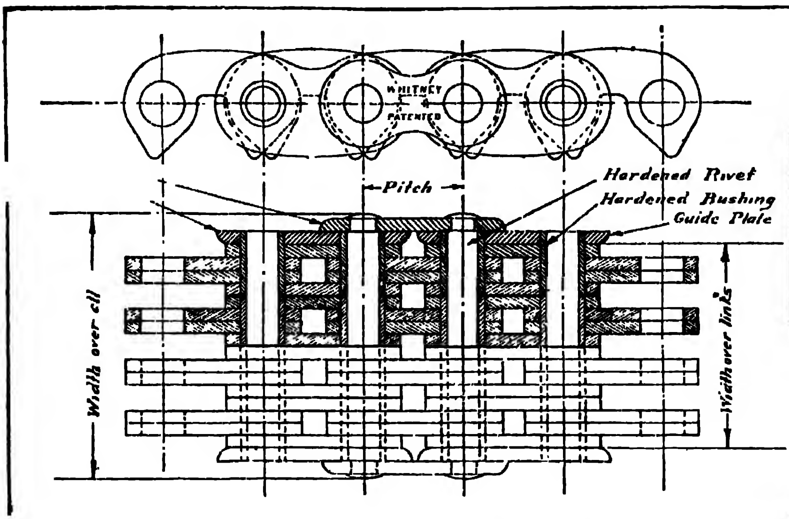


Fig. 389.—Showing Construction of Whitney Silent Chain.

After the horizontal slot has been pushed over the pin, the end carrying the vertical slot is pulled down over the other pin. The chain side links are provided with depressions in which a suitably raised punching in the link locking stamping springs when the locking member has been pushed in place. In the section of chain shown at B, the locking member at the left is about to be pushed in place while that at the right is shown in the position it occupies to prevent loosening of the chain link.

The method of locking the master link on the Baldwin chain is clearly shown at Fig. 390. In this washers of soft steel are used

to fit the locking grooves in the end of the rivet pins. After the washer has been sprung in place, it is tightened around the pin with a pair of pliers. In the Whitney chain, also shown at Fig. 390, the side plates are held by split pins which may be readily removed when it is desired to pull off the side plate. It is often found difficult to replace a large heavy motor truck chain on account of trouble in bringing the links sufficiently close together to slip in the master link. This may be easily overcome by using a simple tool shown at the bottom of Fig. 390. This consists of a pair of hooks made of stock sufficiently small in diameter to go between the rollers and side plates of the chain link. One of these hooks is provided with a right hand thread, the other with a left hand thread. A piece of hexagon bar stock, four or five inches long, is provided, a hole being drilled clear through. One end is tapped right hand to match the thread on one hook, while the other end is tapped left hand to fit the thread on the other hook. When the hooks are started into the ends of the threaded bar, a very effective turnbuckle arrangement is obtained by which all slack may be taken out of the chain and the links brought near enough together to insert the master link.

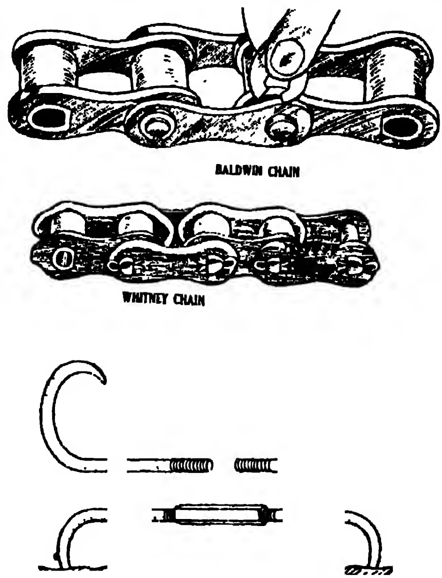


Fig. 390.—Two Types of Quick Detachable Chain Links and a Simple Tool to Facilitate Insertion of Master Link.

If chains are properly cared for they will not wear as quickly

as when neglected. The careful truck driver will remove the chains every week and allow them to soak in kerosene so that all grit will be washed out of the joints. After this, the kerosene is thoroughly wiped off and the chain is immersed in melted tallow and graphite until the lubricant has a chance to penetrate between all the rivets and roller bushings. The surplus lubricant is wiped off of the chain after it has been allowed to cool and the chain replaced. The practice of oiling the chains with an oil can or with grease applied to the surfaces is not conducive to long chain life because it only serves to collect the grit and lead it to the bearing surfaces. The silent chain, which has been adopted in a number of cases for camshaft drive in the engine and for coupling up starting motors and generators to the crankshaft, may also be used for final drive. It has been used in friction drive cars, notably the Lambert, Cartercar and new models of the Metz touring car. Where this type of chain is used it is usually protected by a casing and runs in an oil bath. When mounted in this manner the silent chain is not apt to depreciate rapidly, as is true of the roller chain when the links, rivets and bushings have worn the chain will stretch out of true pitch and will become seriously weakened. If there is unusual wear or lost motion at these points the only remedy is replacement with a new chain. Whenever a new chain is installed on a car, it is imperative to replace the sprockets as well because a new chain will not run well on worn sprockets, nor will new sprockets operate properly with a worn chain.

Live Axle Repairs.—Among the parts of the live axle that demands inspection from time to time are the differential and driving gear assembly, which have been previously described, and those parts of the rear construction upon which its structural strength depends. There are other points, such as spring seats, the brake mechanism and the bearings upon which the various rotating members are carried that must also receive attention. Noise from a rear axle often results when bearings that are too small have been used or when these have been of a type not properly adapted for the work they were expected to perform. For example, a number of axles has been marketed in which only single row or radial bearings have been used to take the thrust between the bevel drive gears in-

stead of supplying bearings especially adapted for that purpose. The pressure of the bevel gear teeth, as soon as it reaches a certain point would cause a wedging of the balls and races, especially when the car is on the lower speed ratios or if the transmission brake is applied sharply at full speed or if the wheel brakes are applied without releasing the clutch. A harsh acting clutch will also impose these intermittent wedging stresses on the bearings. This is unfortunate because if by any such action the ball bearings have been put out of line, the distortion between the inner and outer races will result in rapid bearing depreciation which of course produces considerablo noise. Another trouble met with in semi-floating axles is replacing wheel drive shafts for defective ones that are too short and which do not abut inside of the differential. In this case when one rear wheel skids violently or is thrown against some obstacle on the highway the severe end thrust shock is frequently transmitted to a bearing supporting the differential which results in these members depreciating sooner than they would if subjected only to the load they are supposed to resist. It is considered good practice to transmit the shocks from one wheel to the other through the middle of the axle without engaging the differential housing. This is done by the manufacturer when he establishes a contact between the two inner ends of the wheel shaft. When the shafts are replaced or repaired care should be taken that this mutual abutment takes place as intended. In some designs a large size steel ball is placed between the axle ends, in others, fiber or steel washers having curved and straight sides are used, the curved sides being placed against each other, while the straight sides are placed against the shaft ends. Shafts of three-quarter or full-floated axles are not supposed to abut.

The rear axles of many shaft driven cars are braced with tension rods, but after being in use for a time the vibration of the axle and the up and down hammering action that obtains over rough roads eventually lengthen the rods and relieve their tension, which, of course, results in a cessation of the functions they are intended to perform. The tension rods should be carefully examined from time to time to make sure that they are properly tightened as if loose a certain amount of sagging will take place which

results in lack of alignment of the parts carried by the differential housing which will result in noisy action. Many cases of distorted axle housings have been noticed in light cars that have been operated over rough roads. This will result in the wheels being bowed so that the tops are nearer together than the bottom, as shown at Fig. 391. In many cases the sprung axle housing may be drawn back in line and materially strengthened by the use of a truss rod placed under the differential housing and attached at the wheel end of the axle by some form of clamp, passing around that member.

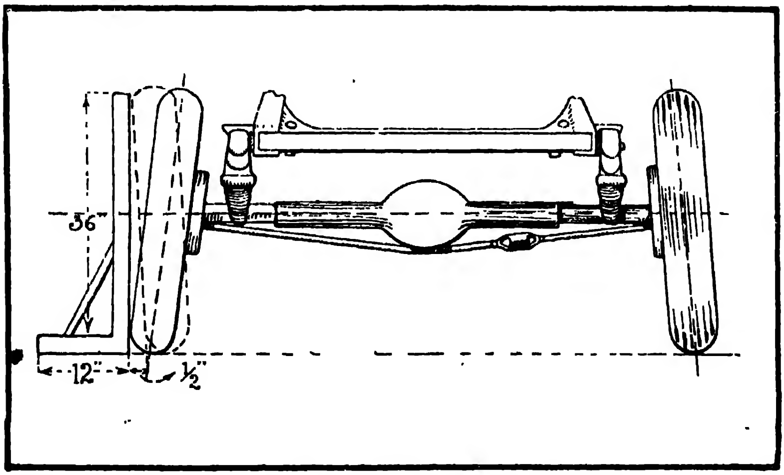


Fig. 391.—Method of Bracing Sprung Rear Construction by Truss Rod.

The rod should be at least half an inch in diameter and be made of cold rolled steel. A turnbuckle is placed in the rod to draw the parts together and straighten out the axle housing. The condition shown in the diagram is exaggerated in order to make the defective condition clearer. It is not possible to take out all the sag if an axle has been neglected and it is also important to notice whether the wheels are loose because of worn bearings or whether the wheel driving axle is bent before any attempt is made to compensate for this defective condition by trussing under the rear construction.

In many cases where the bevel driving gears have worn the repairman has the job of replacing the worn parts. In some cars

the ring gear is riveted to the differential case flange, though in most of the modern designs it is attached to that member by means of bolts. If the threaded retention members are used it is not a difficult proposition to remove the bolts and the old gear and fasten the new one in place. Where the ring gear is attached by rivets, however, an entirely different procedure must be followed. The first step is the removal of the old gear by chipping off the rivet heads with a sharp chisel in order to drive the old rivets out or to drill out the rivet head if this is of the countersunk type. After the rivets have all been driven out and the old ring gear removed, the flange should be carefully gone over and all upstanding burrs should be smoothed down with a file. Any irregularity on the flange will result in the ring gear being out of true, as far as its meshing with the driving pinion is concerned.

Hot riveting is preferable to cold riveting because when the rivets are put in red hot they fill the holes better as they are headed over and additional holding power is secured by the cooling shrink. In order to make a neat job of riveting it is imperative to use a rivet set. A skillful mechanic may be able to form up a head with a peening hammer but this at best is a slow job and there is always some danger of injuring the differential casing or the gear teeth should the hammer slip.

A rivet set is very easily made by using a bar of steel about one inch square and five or six inches long, tapering off the end so it will fit in the space between the gear teeth and the differential casing and forming the depression in the end that makes the rivet head either by drilling in with the point of a drill, or by heating the bar of steel to a good forging heat and making the depression by driving a rounded bar of steel to conform with the rivet head into the headed end.

The usual size of rivet used on small cars is ¼-inch. On the larger pleasure cars, $\frac{5}{16}$-inch or ⅜-inch diameter rivets will be used. The rivet should be sufficiently long so that it will project through the flat surface against which the head is to bear a length equal to 1½ times the diameter of the rivet stock. The work of riveting must be quickly done. The rivets are heated in a forge and when red hot are placed in the hole, the head end down against

an anvil while the projecting end is headed over with a rivet set and a 5 pound hand sledge or machinist's hammer. After the first rivet has been placed, the next one to go in should be put in diametrically opposite. This holds the gear firmly in place against the differential gear case flange, after which the other rivets may be put in as suits the convenience of the operator. It is well to bear in mind that a well rounded rivet head is apt to have more strength than large, roughly flattened heads that have been produced by hammer blows and without the use of a rivet set.

Axle Lubrication.—Many cases of noisy driving gears result from lack of lubricant in the differential housing, and a number of cases of rapid depreciation of live axle bearings have been traced to neglect in oiling these essential parts. The reason for this is that most of the axle members are lubricated through the medium of compression grease cups, which are more or less inaccessible unless the operator gets under the car. The average motorist who takes care of his own car does not enjoy getting under the chassis unless absolutely necessary. Points that must be reached periodically are apt to be neglected, whereas if the oiling was not too much of a task, they would receive regular attention. If a rear axle on a practically new car grinds or hums the first step is to introduce some grease into the differential casing unless the noise is so pronounced that it is evident it must be caused by lack of alignment or poor meshing of the driving gears.

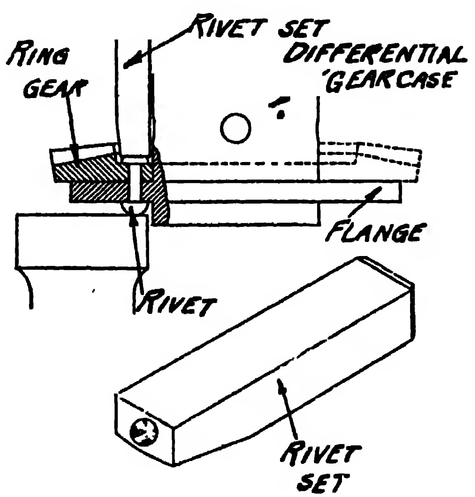


Fig. 392.—How to Rivet Driving Gear to Differential Gear Case.

Most differential housings have a removable cover plate leaving an opening through which grease may be introduced when necessary. It is somewhat of a task to remove this cover, so many makers provide a plug through which the spout of a syringe or grease gun may be introduced to advantage.

A very practical form of grease gun is shown at Fig. 393, A. This is filled with the grease used for oiling the differential gears by drawing the plunger to the extreme outward position and removing the threaded closure member to which the spout is attached. This makes it possible to pack the grease in the pump barrel after which the cover is screwed back. In order to force the heavy lubricant out, a simple ratchet mechanism is provided, worked by a handle, which provides considerable leverage, this working against a series of ratchet teeth on the plunger rod of the pump. By grasping the pump as shown it is possible to empty the syringe with very little exertion by moving the trigger-like lever to push in the plunger to displace the grease. Other forms of grease guns have a threaded plunger rod, which may be screwed in the barrel to force out the grease; some use compressed air.

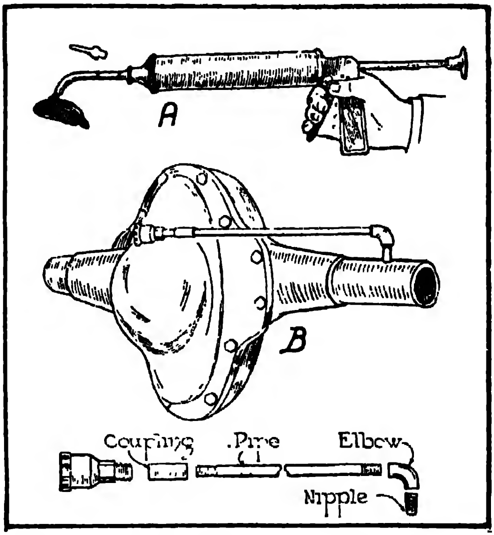


Fig. 393.—Methods of Lubricating Rear Construction.

Where grease cups are fitted in important but inaccessible places the conscientious operator is obliged to reach under the chassis and assume uncomfortable positions, not to mention the ever present danger of soiling the clothing. An easily made and inexpensive

device is shown at Fig. 393, B, which will bring the grease cup out to a point where it may be easily reached. The material necessary consists of a piece of ordinary one-eighth inch gas pipe, an elbow, coupling, and a short nipple which are joined together as indicated. To install the device the cup is removed and the distance measured from the part to be lubricated to the most convenient point where the grease cup is intended to be placed. Practically all compression grease cups are provided with a one-eighth inch standard male gas-pipe thread. When the grease cup is removed from the axle there should be no difficulty in placing a nipple in the opening left by the withdrawal of the grease cup. The elbow is attached to the nipple, after which the piece of pipe, which has been cut the proper length and threaded at both ends is screwed into the elbow at one end and the coupling screwed on at the other. The grease cup is then screwed into the female thread at the end of the coupling. Care should be taken to fasten the pipe at the grease cup end by means of a metal clip, as if it is not securely fastened to some part of the axle it will be apt to break off due to vibration. It should be remembered that it is necessary to fill the entire length of pipe with grease before any will reach the bearing point, therefore it is important that the grease cup be refilled a number of times to make sure that grease will reach the bearings.

No part of the automobile is exposed to more dust and dirt than the operating linkage of the hub brakes. Upon the majority of automobiles no means are provided for effective lubrication of these parts. Any looseness of the bearing pins causes a disagreeable rattling due to rapid wear of the dry bearings. The usual method of lubrication is by a squirt can, oil being applied to the crevices between the moving and stationary parts with a hope that it may find a way between bearing surfaces. It is well to wipe off surplus lubricant from the outside of the joint, as this only serves to attract and hold road dust.

Methods of Retaining Lubricant in Wheel Hubs and Differential Housings.—The retention of lubricant and exclusion of dust is one of the problems confronting the designer of automobile axles that can be solved in a number of different ways. It is important to prevent the escape of grease from the differential housing be-

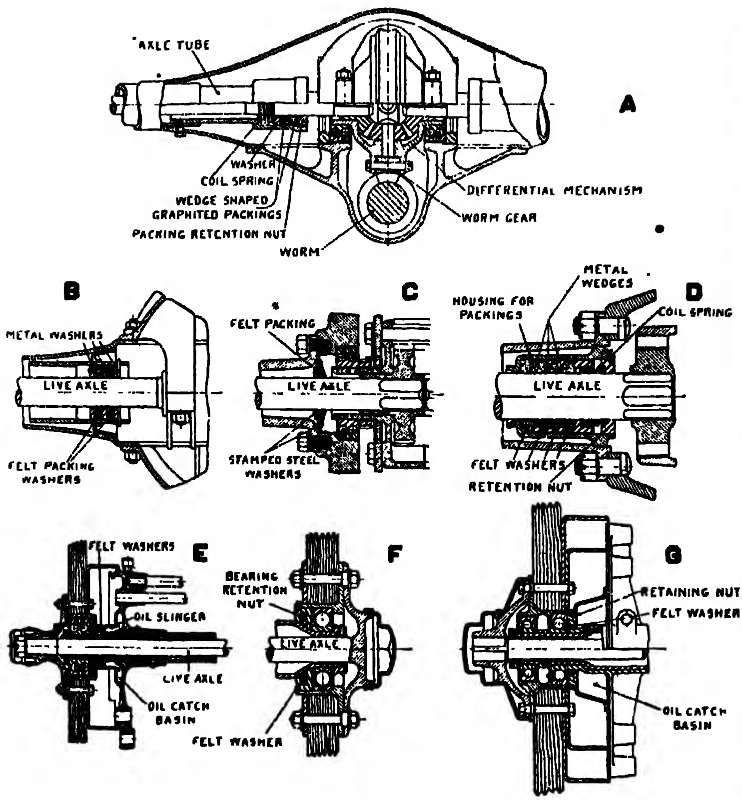


Fig. 394.—Showing Typical Methods of Retaining Grease in Differential Housings and Wheels.

cause it will accumulate on the internal brakes and reduce their efficiency. While it is difficult to overcome leakage due to an excessive supply of lubricant, if reasonable precautions are taken in this respect, an axle housing may be made practically grease tight. A number of oil-retaining methods selected at random and known to give satisfactory results in practice is depicted in accompanying series of illustrations.

A worm gear drive axle is more apt to lose oil because this form of gearing demands more lubricant and of a more fluid nature than

that ordinarily supplied to bevel gear driven axle housings. An ingenious application of a self-tightening stuffing box is used in the construction outlined at Fig. 394, A. The tubular housings that enclose the live axles project into the differential case and have an enlargement at the end closed by a packing retention nut. This bears against one wedge-shaped graphited packing which fits the taper seat of the other packing element. As a certain amount of wear is unavoidable as the shafts revolve inside the packings, some method of keeping the packings properly seated is necessary. This is accomplished by a coil spring which holds the packings in intimate contact with the shaft. When the car rounds a curve and the lubricant is thrown to one side, the space between the sleeve tube and housing acts as a pocket and retains the oil, allowing it to flow back to the bottom of the housing when the car is no longer tilted.

In a number of cases, felt washers form an effective barrier against passage of oil along the shaft, though when these are employed, a supplementary packing member is utilized at the wheel end of the axle. Two felt washers firmly held between steel clamping plates may be fitted as at B, or a special composite member as outlined at C may be substituted. The packing member is inclined as shown, so that the oil carried around by the axle will be deflected back to the bearing housing.

The self-adjusting stuffing box arrangement shown at D is similar in design to that outlined at A, except that more felt washers are used and metal wedges are depended on to keep the washers bearing against the axle. As in the other design, the pressure of a substantial coil spring keeps the metal wedges in firm contact with the felt packings.

There is no better known or more effective method of keeping oil from leaking out of the axle at the wheel end than the patented oil slinger invented by Weston-Mott engineers and depicted at E. The function of this member, which revolves with the wheel, is to throw the oil which leaks by the felt washers into an oil catch basin cast integral with the brake-band carrying plate. A bent pipe at the bottom of this chamber allows the oil to drain off to the ground, clear of the brakes and tires.

The method shown at F involves the use of a tapering axle housing tube and a bearing retention nut carrying a liberal felt washer in an annulus machined therein. Should any oil pass by the felt washer, that member must be renewed. The construction outlined at G is a combination of felt washer to restrain the oil and a catch-basin to hold any lubricant that escapes past the felt packing. The

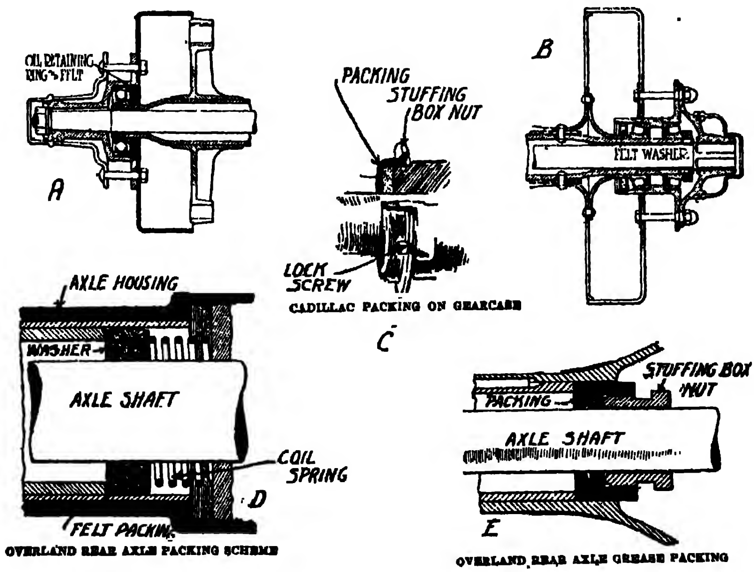


Fig. 395.—Miscellaneous Grease Retaining Methods.

oil container is attached to the casting used to support the brake assembly. This system is used by the Salisbury Wheel & Mfg. Company.

The methods of grease retention shown at Fig. 395 are similar to those previously described. At A, a simple oil retaining ring and felt packing are believed sufficient. At B, we have a modification of the idea shown at A, in which a more liberal felt washer is used which is held in a pressed steel retaining member. The stuffing box idea as shown at C is more often used on transmission gear

cases than on rear axles, but as the gear case is sometimes combined with the differential housing a packing of this form may be found on the rear axle. In order to prevent oil leakage it is necessary to screw up on the packing ring to compress the felt more tightly against the shaft. Before the adjusting member can be turned it is necessary to release the locking screw which must be replaced when the stuffing box has been properly tightened. The automatic stuffing box shown at D is used on some Overland rear axles. This consists of a substantial felt washer held between steel plates, a constant pressure against the washer being exerted by a coil spring. Other Overland models have the grease packing shown at Fig. 395, E. This is the form of stuffing box widely applied in marine use which must be taken up from time to time to compensate for wearing of the felt packing member. If grease escapes from the end of the axle shaft and accumulates on the wheels or tires, this may be taken as a sure indication that the felt packing is worn and must be replaced with new washers. It is not only desirable to keep the grease in the axle on the score of cleanliness, but also on that of economy of lubricant.

Types of Axle Bearings.—At the present time most automobile axles are equipped with anti-friction bearings of various types. These may employ either ball or rollers as load carrying elements. Two common forms of ball bearings are shown at Fig. 396, A and B. The cup and cone type shown in part section at A has been widely applied to the front wheels of light and medium priced pleasure cars and in some cases as a support for the sides of the differential. It is an angular contact form and requires adjustment. The bearing at B is an annular form intended only for supporting radial loads. It is a non-adjustable unit and when it wears it must be replaced with a new bearing.

The roller bearings used are in three main forms, that shown at C using straight rolls of solid steel, that at D using solid taper rolls and the forms at E and F which use straight, hollow rollers. The taper roller bearing and the cup and cone type ball bearings are of the "take up" type. This means that they must be adjusted for smooth running and all lost motion eliminated after the members they support have been assembled in the rear construc-

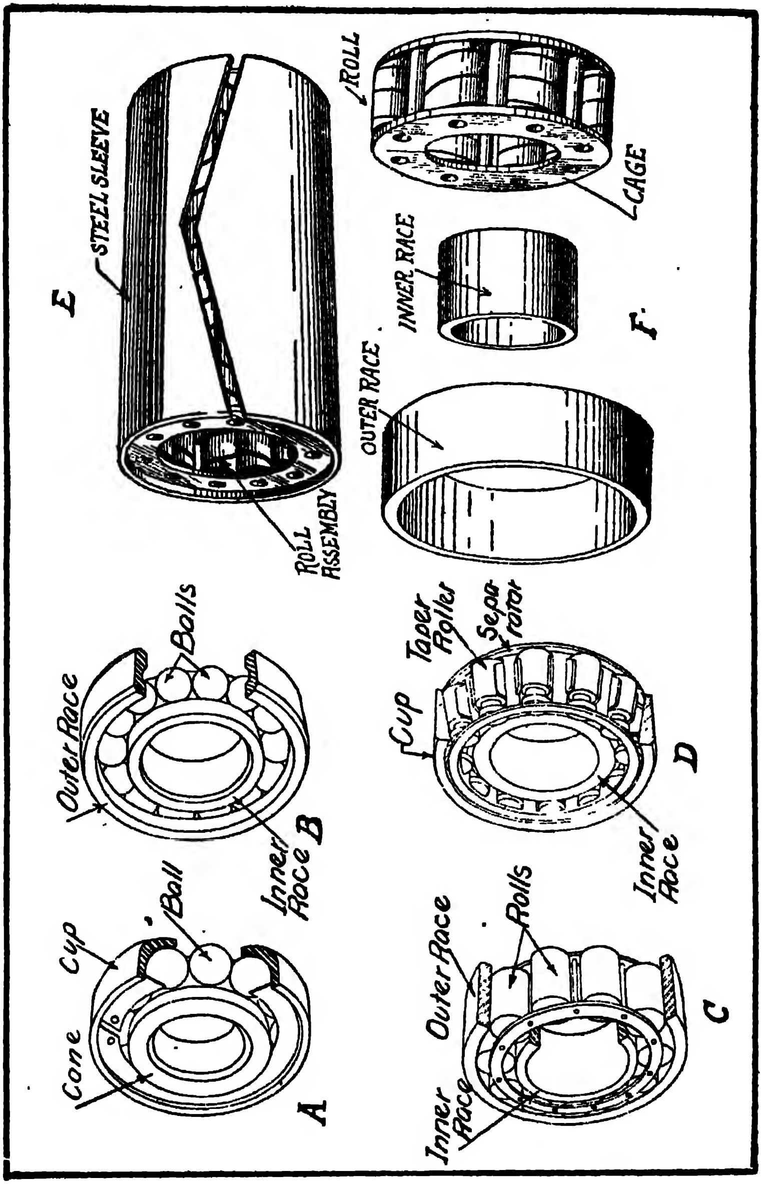


Fig. 396.—Outlining Conventional Types of Ball and Roller Bearings.

tion. Both of these bearings have angular load lines which adapt them to resisting end thrust and radial load in combination. The annular ball bearing shown at D is capable of withstanding slight end thrust but is not generally sold for this purpose. The straight roller bearings have no end thrust capacity and when used in an axle must be supplemented by other bearings, usually ball thrust washers, that are adapted to resist the end thrust.

The Hyatt bearings, which are shown in the standard form at E, and the high duty type at F, have rolls made in the form of close wound spiral springs. This bearing has been very widely used, as

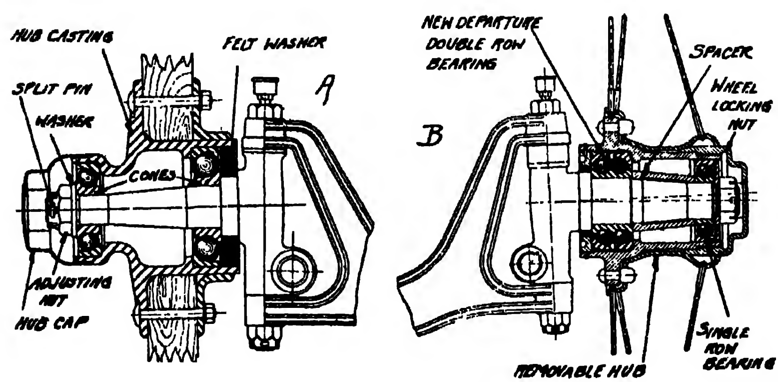


Fig. 397.—Illustrating Two Methods of Mounting Front Wheel Hubs on Ball Bearings. A—Cup and Cone Bearing. B—Unit Type Non-Adjustable Bearings.

is also true of the Timken roller bearing shown at D. In the standard type Hyatt bearing the long rollers are intended to bear directly on the shaft they support. In the high duty form the alloy steel rolls are shorter and are provided with accurately ground inner and outer race rings.

Two applications of ball bearings to front wheel hubs are shown at Fig. 397. That at A uses Radax bearings which are of the angular contact cup and cone type. The method of adjustment is clearly outlined. The wire wheel hub shown at B is mounted on a combination mounting consisting of a double row bearing clamped

firmly in the master hub shell and also tightly held on the wheel spindle. The single row bearing on the outer end of the wheel spindle is not called upon to take any end thrust as the double row bearing is. If any looseness develops in the hub mounting shown at A, and upon examination the bearing components are found to be in good condition, the trouble may be easily corrected by screwing up on the adjusting nut to bring the cone of the outer bearing more firmly in contact with the balls which in turn push the outer race member and the hub it supports over towards the steering knuckle and take out any lost motion which may exist between the parts of the inner bearing. When looseness develops in the hub of the form shown at B, the trouble is usually due to the locking nut on the end of the spindle becoming loose and allowing some clearance between the spacer and the bearing inner races. The remedy for this condition is to tighten up on the nut to bring the bearing races and the spacer into more intimate contact. In examining bearings of the non-adjustable form it is imperative to have these perfectly clean as small particles of dirt will make them run harshly. The impression a dirty bearing will give is just as bad as a worn one will produce, so before a bearing is condemned it should be thoroughly cleaned.

Removing and Installing Ball Bearings.—Many anti-friction bearings are damaged in removal or during application when repairing mechanism in which they are mounted, but this results more from ignorance of their nature than deliberate intent to damage them. A common cause of bearing failure is noted when they are driven in place by blows from an ordinary machinist's hammer applied directly to the bearing face or through the medium of a steel drift or blunt cold chisel. Ball bearings should never be driven in place or removed by use of steel or other hard metal tools because the race members may be permanently sprung or deformed by this treatment. Wherever the construction permits, which is true of most automobile applications, bearings should be removed by direct application of pressure to the part that is tightly fitted. When a bearing is mounted in a wheel hub, as indicated at Fig. 398, a simple form of wheel puller can be employed to advantage. This is a substantial casting of malleable iron or bronze

made approximately the same shape as the hub cap, threaded inside to fit the hub and having a substantial set screw at least ¾-inch diameter passing through the threaded boss at the center. The screw should be long enough to pull the wheel and bearing entirely off the spindle or axle tube. A shouldered plug of steel with a depression drilled in to locate the screw point may be pushed in the hollow tube to centralize the screw pressure. In use, the wheel

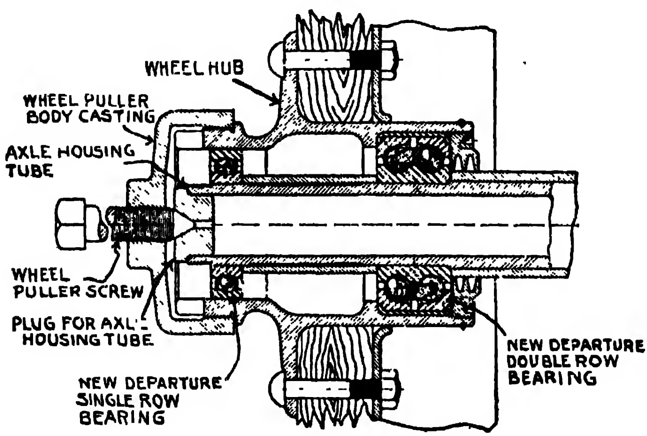


Fig. 398.—Showing Construction of Simple Wheel Puller for Removing Wheel Hub From Full Floating Rear Axle.

puller casting or wheel is kept from turning, so that as the screw advances, it pulls off the wheel and the bearing it contains.

A modified form of puller having two arms and a cross beam that can be used when a bearing cone must be removed from an axle or spindle is outlined at Fig. 399, A. An attachment to permit it to remove a bearing of the unit type such as a single or double row annular without exerting any pressure on the balls or outer race is clearly depicted at Fig. 399 B. This consists of a split casting adapted to be clamped loosely around the shaft back of the bearing inner race and any pressure exerted to remove the

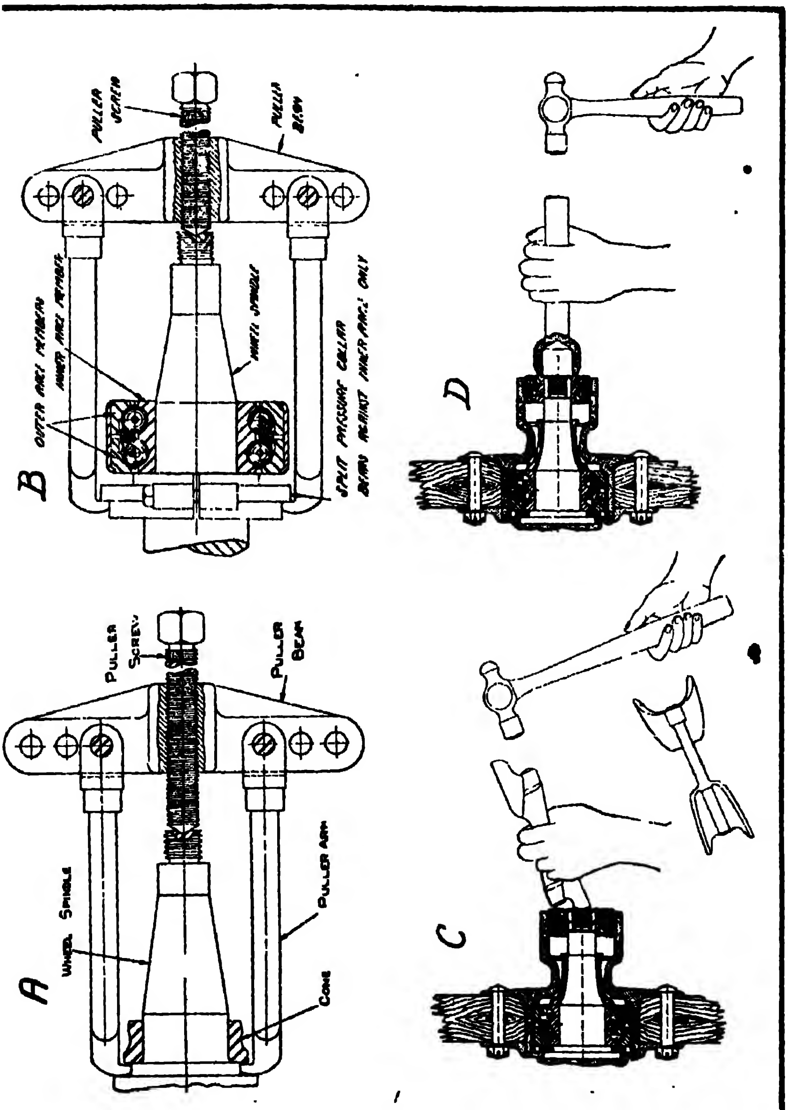


Fig. 399.—Methods of Removing and Installing Ball Bearings Without Damaging Them.

bearing is applied directly against the member which is a force fit on the shaft. When any form of hub or bearing puller fails to start the member to which it is applied by direct pull, its action may be accelerated after the screw has been tightened sufficiently to place the parts under a certain initial tension by a few sharp, well directed hammer blows on the beam or main body of the device.

In all cases where possible, the pressure applied to remove a bearing or part should be exerted directly against the portion that

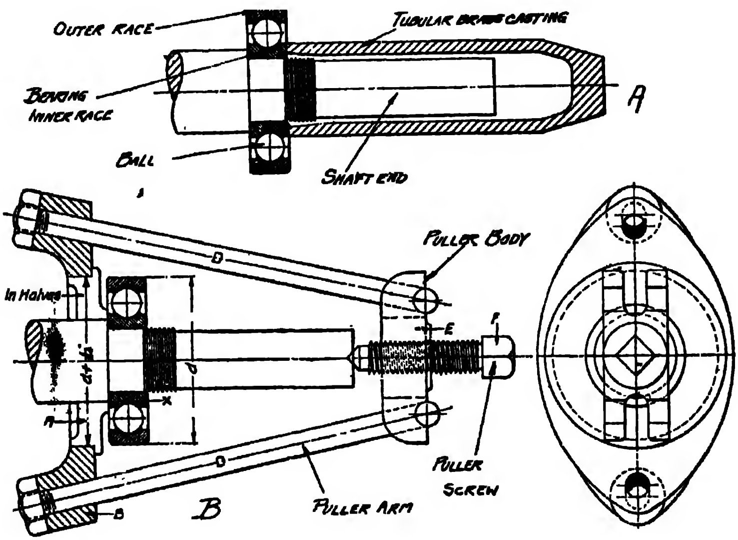


Fig. 400.—Simple Tools for Ball Bearing Installation and Removal.

is a tight fit on the shaft or in the housing. In most cases it is the inner member of the bearing that is a force or press fit on the shaft, the outer race member is usually a push fit in the housing and may be easily removed. If it is necessary to force the bearing off with a series of blows, always use a brass or hard babbitt metal bar or drift between the bearing and hammer, or even a piece of hard maple, hemlock or oak. Do not direct all the blows at any one point on bearing as this tends to cramp it and will make it

harder to drive off. Distribute them evenly around the entire circumference, always having successive blows at points diametrically opposite. When driving bearings in place, it is always best to use some form of soft metal yoke member as shown at Fig. 399, C, or tubular section piece as shown at Fig. 399, D. With either the yoke or the other tubular form the hammer blows are distributed evenly and the bearing is driven in place without injury to either shaft or bearing components. When a double fork member is used, one end can be made to drive against the inner race member while the other can be spread enough to fit the outer race if desired.

The method of driving an inner race in place shown at Fig. 400, A, is recommended by the Hess-Bright Bearing Company. This is a cast brass tubular member proportioned about as shown. Malleable iron or any relatively soft material will answer in place of the brass. It is possible in many cases to make very satisfactory bearing installing members of standard brass pipe. Most ball bearings have the size number stamped on the side of the inner race. When installing Hess-Bright bearings always place the unnumbered side on first when driving in place. The tool shown at Fig. 355, B, is recommended for removing bearings. The essential point to observe is to exert a steady, uniformly distributed pull on the back side of the inner race in pulling that member off the shaft, instead of against the outer race and the balls. The method of operation is very simple, the inner split ring A is placed back of the inner race X. The split ring is held together by a solid outer ring B placed on its circumference having holes for the straddle bolts D, directly over the joints in ring A. The outer ring B is connected to the cross bar E by the two straddle bolts D. Cross bar E is supported by the set screw F entering the shaft center hole and the bearing is easily withdrawn from the shaft by applying a wrench to the set screw.

In adjusting cup and cone ball bearings or taper roller bearings it is necessary to make the adjustment very carefully in compensating for lost motion that exists in the assembly. The condition of the bearings may be determined without difficulty when these are used in the wheels by jacking up under the axle to raise the wheel clear of the ground and thus relieve it of car weight, then by

grasping the wheel rim at opposite points and attempting to shake the wheel. Any looseness in the bearings can be detected by lost motion between the wheel hub and spindle. Care should be taken not to confound this lost motion with looseness in the steering knuckle supporting pin.

In taking up lost motion when any type of adjustable bearing is employed, considerable judgment must be exercised in screwing up on the adjusting member not to get this up too tightly and impose an injurious end pressure on the balls or rollers. An excess pressure that will stress the bearing parts dangerously will not make much difference in the wheel resistance when turned by hand, though when the car weight must be sustained at high speeds or when going around corners the resistance will be increased materially and bearing endurance reduced in proportion. A safe rule to follow is to take up the wear by screwing in the adjustment nut enough so the "shake" or looseness will be eliminated and yet permit the wheel to "spin" for a few revolutions when given an initial impulse. Many motorists and even inexperienced mechanics commit the error of adjusting bearings of the "take up" type too loosely. This is not desirable, any more than fitting parts too tightly together is. Always lock adjustment nut firmly in place when proper adjustment has been secured.

In some gear boxes and axles, the bearings are shim adjusted. A number of thin washers of sheet brass may be interposed between the bearing cup and the retainer cap. When taking down an assembly of this nature always keep the shims from any bearing box together and tagged for future identification to insure that the adjustment made in the factory will be maintained after reassembly in the repair shop. If the bearings are loose for any reason, add thin shims about .005-inch thick to the others, until there is no appreciable lost motion and yet no binding between bearing parts.

A word of caution is necessary to the inexperienced motorist when tightening adjustable bearings of the cup and cone type. The first thought when looseness is detected is to tighten them by bringing the cones into closer engagement with the balls and thus force these members more tightly against the bearing cups. This should never be done without examining the condition of the cup, cone

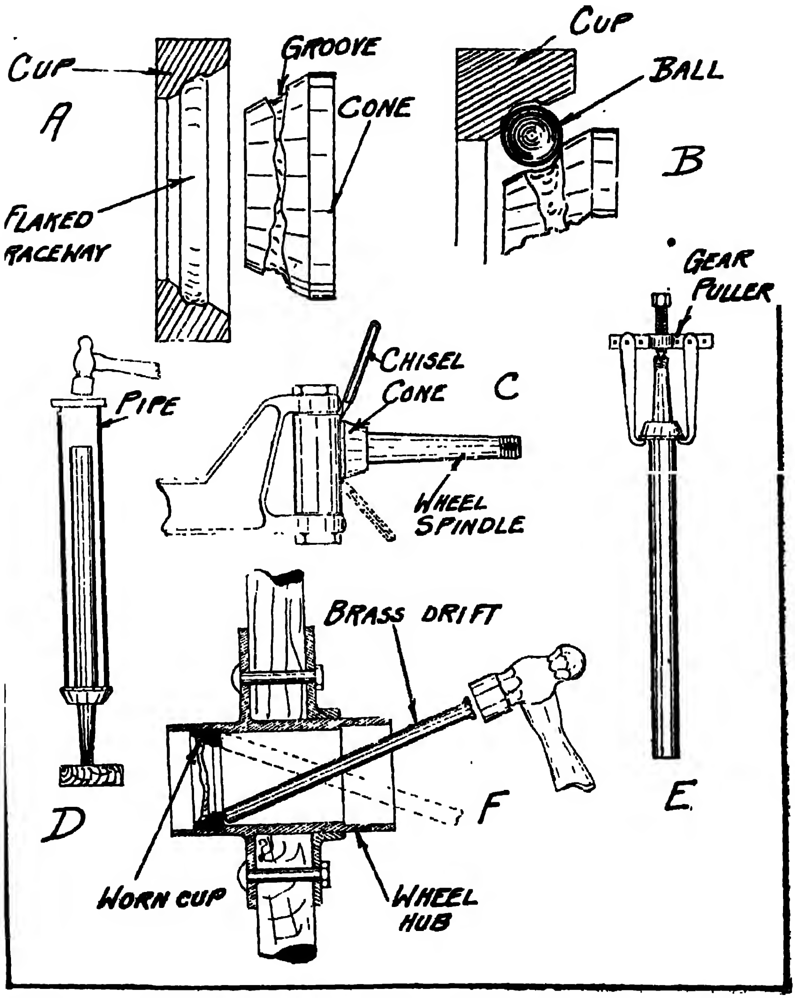


Fig. 401.—Illustrating Depreciation in Cup and Cone Bearing at A and B and Method of Removing Cone from Wheel Spindle at C. Use of Drift in Driving Out Anti-Friction Bearing Cups from Wheel Hub Outlined at F.

and ball and separator assembly. If a groove has worn in the cup and cone, as shown at Fig. 401, A, due to flaking away of the metal under load, nothing will be gained by adjusting the bearing by

bringing the cone into closer engagement. This will cause the balls to ride on the sharp edges of the grooves as shown at Fig. 401, B, which will result in rapid destruction of the entire bearing, because either a broken ball or some of the flaked particles of steel will get between the bearing parts. When adjustable bearings be-

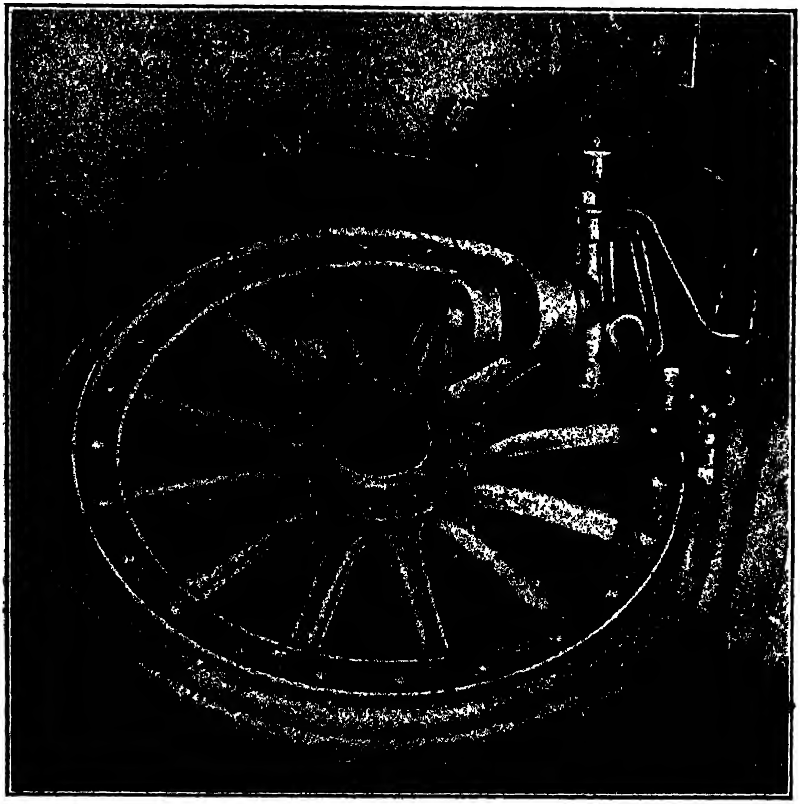


Fig. 402.—Wheel Removed from Motor Truck Front Axle to Show Arrangement of Bearings on Steering Spindle.

come worn it is necessary to replace both worn cup and cone as well as entire new series of steel balls.

When it is necessary to replace a bearing the old one must be removed, and while a number of tools has been described that work very well on modern cars, some difficulty will be experienced

on those of early design because no provision was made for easy removal as is now the case. The easiest method of removing a bearing cone when it is forced on a wheel spindle and no opportunity is present for using a special puller is shown at Fig. 401, C. A sharp cold chisel is used, this being driven between the cone and the shoulder against which it is forced on alternate sides, first above, then below, and then on either side until the cone has been worked off of the wheel spindle. Similarly a ball or roller bearing cup that is a tight fit in a wheel hub may be driven out by careful application of a brass drift as shown at Fig. 401, F. The hammer blows should never be directed at any one point of the cup because if the pressure is applied at one point only it will cramp the cup in the hub and any further hammering after the cup is "cocked" will only serve to make it more difficult to remove. The method of removing a cone from a long shaft by a piece of pipe as at B, and by a gear puller as at Fig. 401, E, is generally understood by repairmen. If the cone resists either of these methods, it can be forced off under an arbor press.

Lubrication and Enclosure.—Ball bearings do not require the continual application of lubricants that is called for by plain bushings, and, to a lesser degree, by roller bearings, but this does not mean that lubrication can be neglected or done carelessly. The important point to observe is that none but pure mineral oils or greases be used, as any that show traces of acid or alkali, or that may become rancid from oxidization will cause etching and roughening of the highly finished surfaces of the balls and races. Lubricants best adapted range from light machinery oils, used in small high speed bearings, such as fitted in magnetos, lighting generators or starting motors, to the viscous grease utilized in those subjected to heavy loads and revolving at low speeds as wheel bearings or differential bearings. Wherever the bearing can be immersed in a bath of oil and properly protected from water and grit a lighter oil can be used, but when the bearings are housed where dirt or water may get in, then the use of ample quantities of viscous lubricant, such as vaseline or other mineral grease that is free from acid prevents the foreign matter working in between the balls and races. Ball or roller bearings are generally enclosed in

such a manner that there will be no opportunity for dust, grit or water to enter, and if this function is properly performed the closure will also be tight enough to prevent escape of oil.

Importance of Proper Maintenance Emphasized.—Despite the extreme care taken in manufacture, bearings of the leading makes sometimes fail in service, and the motorist or average dealer, ever ready to condemn that which he does not fully understand, attrib-

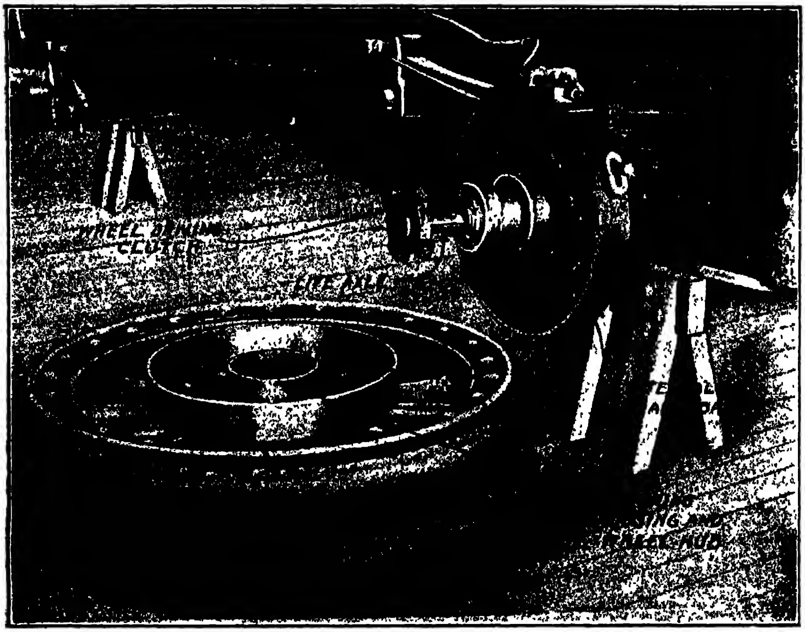


Fig. 403.—Wheel Removed from Full Floating Axle of Motor Truck to Show Method of Ball Bearing Installation.

utes the cause of failure to careless workmanship or the use of poor materials on the part of the producer, whereas the trouble is often due to conditions which are entirely within the user's control. A ball bearing must have a certain amount of running clearance, but in the leading types this is much less than in a plain bearing, it being common practice to allow a radial freedom never greater than .001-inch. In connection with this, in single row radial bearings an axial freedom or end play of the inner race relative to the

outer is allowed, this varying with the size of the bearing between the extremes of .0005-inch to .005-inch for new bearings. Thus a properly made and installed ball bearing will not deteriorate in the accepted sense of the term as applied to plain boxes; that is, there will be no reduction of diameter or increase in bore. If there is an excessive amount of axial or radial motion the cause is admittance of some abrasive between the components of the bearing

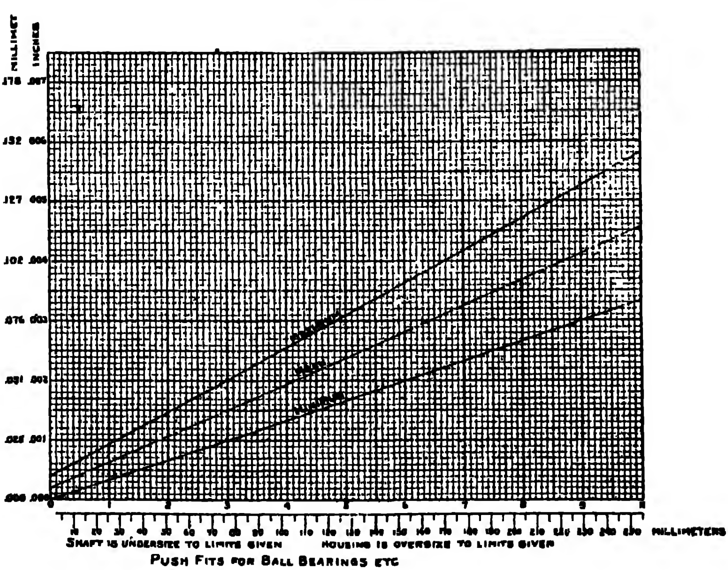


Fig. 404.—Chart Showing Allowances for Push Fits for Ball Bearings, etc.

or by overloading. As is true of any bearing, the amount of wear will depend upon the cutting power of the grit, the pressure the bearings are subjected to, and the amount of time the foreign matter is between the working surfaces.

There are places where a certain amount of dirt and metallic particles are always present. For example, many cases of trouble in rear axle and transmission case bearings have been definitely traced to the presence of minute particles of metal ground off from

the gears, or sand loosened from the interior of the gear case or rear axle housing castings. In sliding gears, especially when operated by an inexperienced person, there is a constant clashing of the pinions in changing speed, which tends to loosen particles of metal from the teeth. These fall into the lubricant, and are churned around and often find their way into the ball races. The

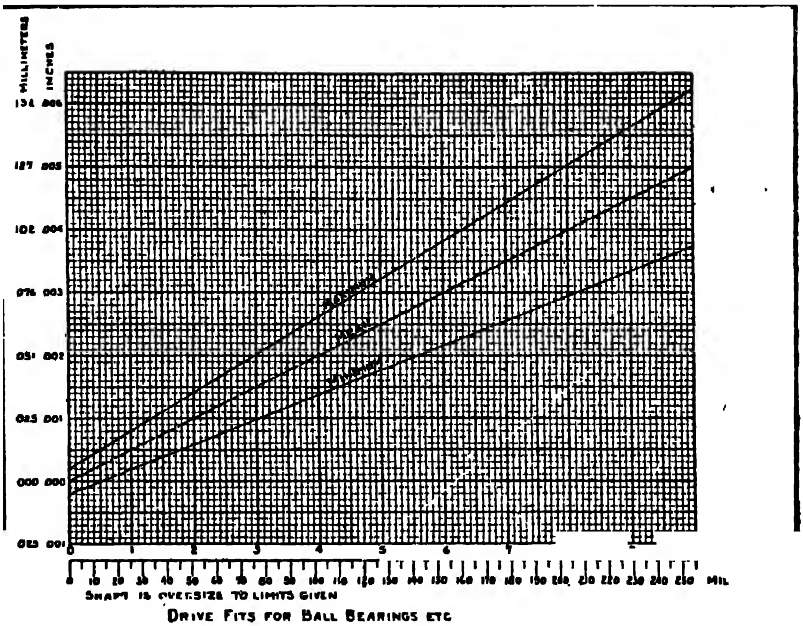


Fig. 405.—Chart Showing Drive Fits for Ball Bearings, etc.

rapid failure of the bearing is the inevitable consequence. The importance of proper mounting has been so firmly impressed upon the automobile manufacturers that but little trouble is caused from improper installation in cars of reputable makes. Hence we are forced to consider the user in many cases when analyzing causes of bearing failure.

There is a condition that is beyond the control of the manufacturers of either the bearings or the mechanism to which they are fitted, and that is the use of impure oils, and carelessness in washing the running gear and other parts of automobiles. Many

Table of Standard Fits.

Standard Fits in Housing Housing Oversize. (Push Fit)				Standard Fits of Shaft Shaft Undersize. (Push Fit)				Standard Fits of Shaft Shaft Oversize. (Drive Fit)			
Bearing Diameter		Housing Diameter		Bearing Bore		Shaft Diameter		Bearing Bore		Shaft Diameter	
M/M	Inches	Maximum	Minimum	M/M	Inches	Maximum	Minimum	M/M	Inches	Maximum	Minimum
28	1.1023	1.1030	1.1024	10	.3937	.3935	.3930	10	.3937	.3941	.3938
30	1.1811	1.1818	1.1813	12	.4724	.4721	.4716	12	.4724	.4728	.4725
31	1.2204	1.2213	1.2206	15	.5906	.5902	.5897	15	.5906	.5910	.5904
32	1.2598	1.2606	1.2599	17	.6693	.6689	.6683	17	.6693	.6697	.6692
35	1.3779	1.3788	1.3781	20	.7874	.7870	.7864	20	.7874	.7880	.7874
37	1.4567	1.4575	1.4568	22	.8661	.8656	.8650	22	.8661	.8667	.8661
40	1.5748	1.5758	1.5751	25	.9843	.9837	.9831	25	.9843	.9848	.9842
42	1.6535	1.6545	1.6538	27	1.0630	1.0623	1.0617	27	1.0630	1.0636	1.0630
44	1.7322	1.7333	1.7325	30	1.1811	1.1805	1.1799	30	1.1811	1.1818	1.1812
47	1.8504	1.8515	1.8507	35	1.3779	1.3772	1.3764	35	1.3779	1.3787	1.3781
52	2.0472	2.0484	2.0476	40	1.5748	1.5741	1.5733	40	1.5748	1.5758	1.5750
62	2.4409	2.4422	2.4415	45	1.7716	1.7708	1.7700	45	1.7716	1.7727	1.7719
72	2.8346	2.8361	2.8352	50	1.9685	1.9677	1.9668	50	1.9685	1.9697	1.9688
80	3.1496	3.1513	3.1505	55	2.1653	2.1644	2.1635	55	2.1653	2.1666	2.1657
85	3.3464	3.3484	3.3473	60	2.3622	2.3612	2.3603	60	2.3622	2.3637	2.3627
90	3.5433	3.5453	3.5441	65	2.5590	2.5579	2.5570	65	2.5590	2.5606	2.5596
100	3.9370	3.9391	3.9379	70	2.7559	2.7548	2.7539	70	2.7559	2.7576	2.7566
110	4.3307	4.3330	4.3318	75	2.9527	2.9516	2.9506	75	2.9527	2.9545	2.9535
120	4.7244	4.7272	4.7256	80	3.1496	3.1485	3.1472	80	3.1496	3.1515	3.1504
125	4.9213	4.9239	4.9225	85	3.3464	3.34500	3.34390	85	3.3464	3.34835	3.34725
130	5.1181	5.1209	5.1194	90	3.5433	3.54185	3.54075	90	3.5433	3.54545	3.54435
140	5.5118	5.5147	5.5132	95	3.7401	3.72865	3.72765	95	3.7401	3.74255	3.74115
150	5.9055	5.9085	5.9069	100	3.9370	3.92545	3.92435	100	3.9370	3.93965	3.93815
160	6.2992	6.3024	6.3007	105	4.1338	4.12215	4.12095	105	4.1338	4.13656	4.13495
170	6.6929	6.6963	6.6945	110	4.3307	4.32905	4.32775	110	4.3307	4.33335	4.33195
180	7.0866	7.0902	7.0884								
190	7.4803	7.4841	7.4822								
200	7.8740	7.8780	7.8760								
210	8.2677	8.2720	8.2698								
215	8.4646	8.4690	8.4668								
225	8.8583	8.8629	8.8607								
240	9.4488	9.4537	9.4514								
250	9.8425	9.8476	9.8454								
265	10.4331	10.4386	10.4360								

Fig. 406.—Table of Standard Fits for Ball Bearings.

cases of failure of wheel bearings have been directly attributed to rust caused by the indiscriminate application of a stream of water at 40 or 50 lbs. pressure per square inch which is not uncommon in many city water mains, to the parts of the car in which they are mounted. The water finds its way into the bearings, causes the highly finished surfaces of the balls and races to rust, and the extreme accuracy in manufacturing and the care of installing is fruitless in preventing breaking down of the bearings. The user will not deliberately clean off the parts of the power plant with a hose, the evil effects of water at this essential point having been brought to his attention too forcibly by troubles in carburetion and ignition, yet the same person who is so extremely careful of the

motor, will spray other parts, fully as important in the duties they perform, with a stream of water under high pressure.

That rust is absolutely destructive to ball bearings has been thoroughly proven in so many instances that the contention cannot be questioned. Of what value is extreme accuracy of finish of the balls to .0001 of an inch if the advantages accruing are to be mitigated by deposits of rust of much greater thickness than the limit established in manufacturing. Such a condition can be as easily recognized by the novice as by the most expert for even if the bearing has been cleaned so that no ferric-oxide is visible to the eye, there will be a number of pits or depressions on the various parts of the bearings, especially at the highly finished ball surfaces, which are clearly evident. While these minute irregularities are sometimes caused by overloading and the flaking off of the metal which results from this condition, if due to causes other than rust and acid, the roughness would be confined to the ball tracks, whereas excoriations resulting from chemical action will be in evidence on all parts of the bearing.

It is a known fact that many oils and greases contain acids or alkalis, either as a necessary component of their chemical composition (as in some animal fats that contain stearic acid) ; as a part of some filler used to adulterate the oil or alter its viscosity, and sometimes as a residue of some of the processes of purifying that obtain in refining from the crude product. The presence of acid in lubricants will cause an etching with irregular edges, in contrast to the clearly defined rust marks. A good lubricant for bearings is a slush made of pure vaseline and lighter mineral oil this being heated to make its viscosity less and enable it to penetrate all parts of the bearings, no matter how minute the spaces. When the bearing has been dipped in this and allowed to remain long enough to permit the oil to reach all parts, it is taken out and allowed to cool and the surplus lubricant is wiped off the outside. Such a mixture will stay in place and will not run out like lighter oils, and at the same time its viscosity is not so high that it will produce unnecessary friction.

How Bearings Should Be Cleaned before Examination.—Another point that can be criticized is the common method of clean-

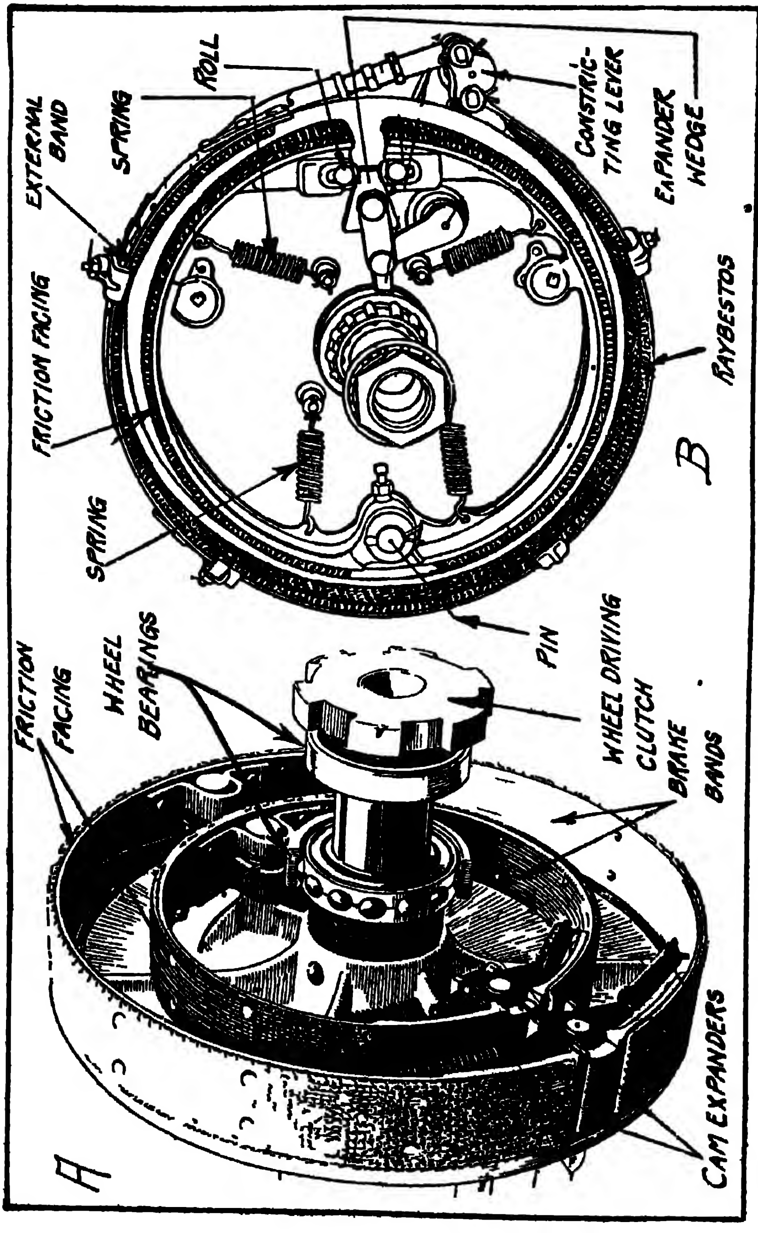


Fig. 407.—Illustrating Construction of Internal and External Brakes.

ing ball bearings in the average car repair establishment or machine shop. They are often dipped in dirty gasoline in which old gears and other parts have been previously cleansed, and this material is often so full of metallic particles, that as soon as it is stirred up enough to disturb the sediment, instead of having a clean bearing, one has filled it with deleterious substances without knowing it. A simple solution of common washing soda and hot water, such as is used in many shops for cleaning greasy parts and assembled bearings at the completion of the manufacturing process offers important advantages. This can be easily made by taking about a handful of the soda to the pail of boiling water. The cleaning agent should be kept nearly at boiling point while in use. The bearings are placed in a wire basket, or hung on a wire and dipped in an alkali solution a few times to remove all dirt; then they are immersed in clean kerosene and given a swirling motion to have this material thoroughly clear out all traces of the soda. The bearings should not be allowed to remain in the wash more than a few minutes at the most, and a few dippings are all that is necessary to clean them out thoroughly and cut all the hard and rancid grease or remove any metallic dust present. After examination of used parts, if the bearings are clean, the surfaces bright and there is not too much looseness, they are in good condition.

A little attention given to careful inspection and consistent lubrication of bearings will be amply compensated for by the increased service obtained and augmented efficiency. The important rules upon which efficient ball or roller bearing service is based can be summed up in a very few words.

First, inspect the bearings from time to time and see that they are clean, and the lubricant does not contain foreign matter, especially in gear boxes and differential casings.

Second, be careful in supplying new lubricant that it is free from acid, alkali, vegetable or animal fillers or other deleterious substances.

Third, when installed in exposed parts of motor cars, be careful when washing not to direct the stream of water directly against bearing housings of the parts.

Brake Forms and Adjustments.—The brakes used to retard

motor car motion are a part of the car that are not only used, but which are often apt to be abused. Brakes are of two general forms, the internal type as shown at Fig. 407, A, and the external constricting band type as exemplified by the outer brake of the assembly shown at Fig. 407, B. Internal brakes may be either metal shoes that are in metallic contact with the brake drums attached to wheel hubs when applied, or members faced with some asbestos frictional material which can be replaced when worn. The internal brakes may be cam-expanded as the forms shown at A are or may be worked by a wedge expander as the internal brake expanders of the assembly shown at B. As a rule no adjustment is provided on cam expanded brakes in the brake construction itself. On external brakes, means of adjustment are usually included.

When full movement of a hand lever or pedal fails to engage an internal brake the first step is to remove the wheel to make sure that the slipping is not due to deposits of grease or to worn brake facings. If the brake facing is clean and not worn unduly, the only practical means of adjustment is by tightening up on the operating linkage. This is easily done by shortening the brake control rod. In the construction shown at Fig. 408, B, this is easily accomplished by turning up on a turnbuckle set into the brake rod. In all cases, even if the turnbuckle is not provided, the clevis at the end of the rod may be screwed up further on the rod which has the same effect as shortening the rod by a turnbuckle would have.

Care should be taken in adjusting brakes by altering the length of the brake rod to have the brakes on both wheels take hold at the same time. In the construction shown at Fig. 408, A, this may be done by unloosening the clamp bolts and setting the lever operating the right brake at the proper point in the slot of the master lever which also operates the left brake. On an external brake of the form shown at Fig. 408, C, the means of adjustment is readily perceived. With an external constricting brake it is merely necessary to reduce the circumference of the brake band by screwing up an adjustment to provide for minor depreciation of the brake lining.

On the Overland cars, when it is desired to adjust the brakes this is easily done by loosening a clamp bolt passing through the

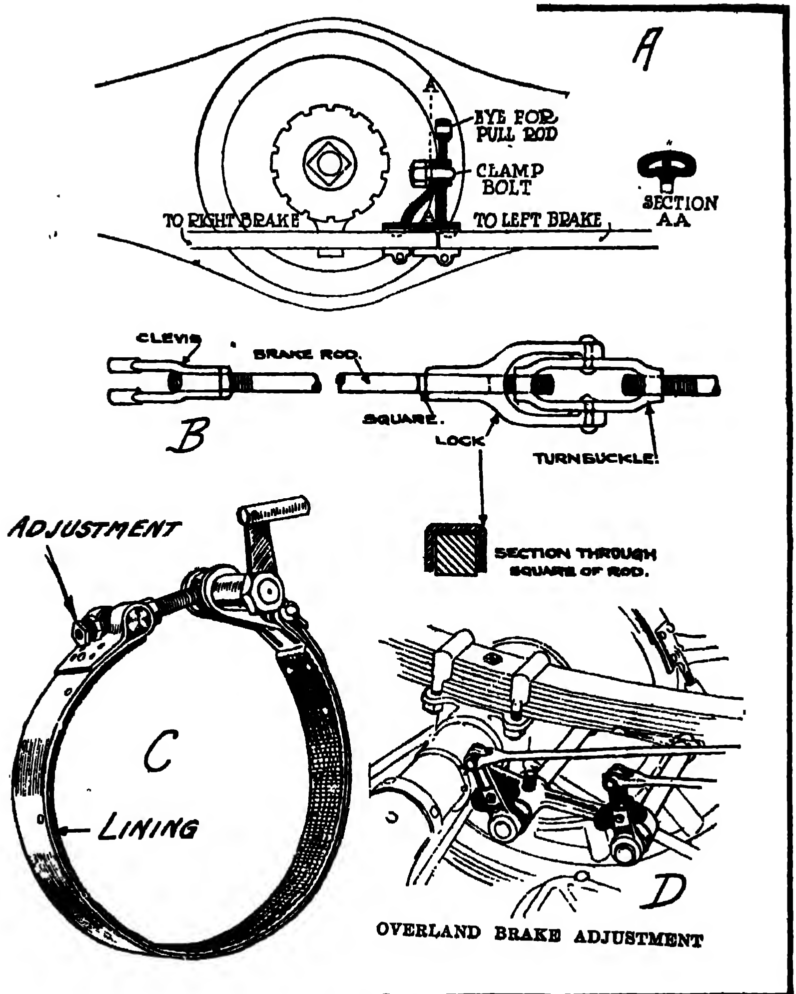


Fig. 408.—Showing Methods of Brake Adjustment.

lever to which the rod is connected and a slotted actuating member pinned to the shaft employed in operating the brakes. It is merely necessary to rock the member over so that the brake parts will be nearly in engagement with the brake lever or pedal fully released and then to maintain adjustment by screwing the operating lever

tightly against the actuating member with the clamping bolt. Sufficient range of adjustment is provided to take care of all brake slippage other than that caused by worn brake lining. This method of adjustment is clearly shown at Fig. 408, D.

Expanding brakes are harder to fix than constricting brakes especially if they are of the solid shoe form and not provided with frictional material. The first step in examining the internal brake is to remove the wheel which is done with a wheel puller as shown at Fig. 409, A, if the rear construction is of the semi- or three-quarter floating type. The full floating wheels may be removed as shown at Fig. 398. When the brake shoes are of the solid cast form an adjustment for depreciation may be made, as shown at Fig. 409, D, providing some of the wear is at the point where the cams act to spread the brake shoes apart. It is possible to put a thin piece of hardened steel on the worn end of the shoe by using dowel pins or flush headed screws. This spreads the brake shoes out slightly, the amount of spreading, of course, depending upon the thickness of the applied pieces and makes it possible to bring the shoes into positive engagement with the brake drums with but small movement of the expanding cams. If the brake shoes themselves are worn and it is not easy to secure new ones, the surfaces may be restored to efficiency by the application of thin sheet brass or steel, which material is firmly held in place by rivets and which has the effect of restoring the worn segment or shoe to its original contour. When pieces are applied to the brake shoes care should be taken in refitting the wheels that the shoes do not bind against the drum when the brake leverage is released. Any high spots existing must be smoothed off with a file in order not to heat up the brake drum through useless friction when the car is in operation.

A typical brake assembly is shown at Fig. 409, D. This is used on some models of the Cadillac car and consists of an internal expanding band and an external constricting one. Adjustment of the service brakes is made by turning the screw S which is on the back of the brake carrier until the part of the band opposite it is brought as close as possible to the brake drum without touching it. Next adjust the nuts T on the eye bolt until the lower half of the band lining just clears the drum. The nut V on the upper end

of the eye bolt is so adjusted as to bring the lever W to the position shown in drawing when the brake is applied. With the brake released the clearance between the lining and the drum should not be over $\frac{1}{32}$-inch, and if more clearance exists it may be reduced by the set screw X in the rocker lever Z.

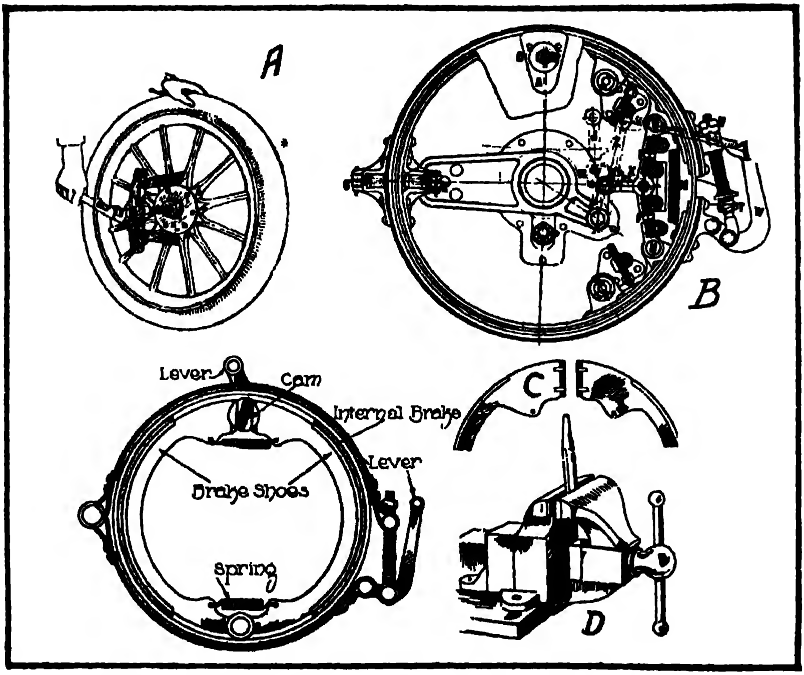


Fig. 409.—Hints on Adjusting Internal and External Brakes.

The internal brake is constructed to be adjusted for clearance between the internal band and the drum without removing the wheels. Jack up the axle so the wheel will clear the ground to permit revolving it by hand. A cover A will be found on the brake drum which can be removed by unscrewing the lock nut B and turning the bolt to the left about a quarter turn until the clamping bar D is released. Next rotate the wheel until the opening registers with the adjusting screw E carried at the back part of the brake band or at the point opposite the expanding toggle

mechanism. Turn the screw E until the part of the brake lining opposite it is brought as close to the inner surface of the brake drum as possible without touching it. Turn the wheel until access is obtained to the six locking screws N and loosen these. This is done by bringing the opening in the brake drum opposite each screw in turn and turning these with a suitable socket wrench. Then turn the two adjusting screws F F which have right hand threads on one end and left on the other until the center of the pin G stands about three-quarters of an inch back of an imaginary vertical line drawn through the centers of the two pins H H when the brake is applied. With the brake released adjust the screw I in the lever J and the stop screws K K until the lower and upper parts of the brake band lining clear the drum by about $\frac{1}{32}$-inch. The three coil springs M should have sufficient tension to hold the brake band sideways and against the stop screws K K so it will not rattle. It is important that the screws M be locked after completing the work, also that the cover in the opening of the brake drum be replaced and fastened securely.

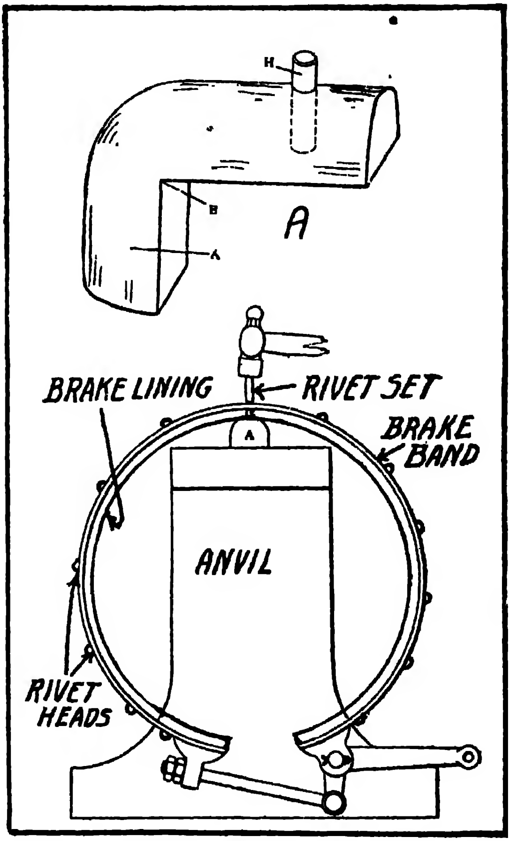


Fig. 410.—Simple Fixture to Facilitate Riveting Brake Lining to Steel Brake Bands.

If the brake lining is worn it should be removed by chipping off the rivets and driving them out of the hole in the brake band. A piece of new lining is cut to the proper length and holes are drilled through it to coincide with those in the brake bands. The best method is to drill only two holes at a time and fit the lining carefully to one end of the brake band, then drilling in the next two rivet holes and after the lining is securely fastened in place to go on to the next rivets. It is important to use copper rivets having reasonably large heads that will not pull through the material and to countersink the material enough so the rivet heads will be firmly embedded below the surface so as not to come in contact with the brake drums. Some cases of slipping brakes have been traced to projecting rivet heads which did not permit the friction lining to come into contact with the brake drums.

A simple fitting which can be placed in an ordinary bench vise for riveting against is clearly shown at Fig. 409, B. This is an ordinary steel drift having a flat point of the same size as the rivet head. The fitting shown at Fig. 410, A, may be placed in a common vise or may be formed to fit the pritchell hole in an anvil. This piece may be made of mild steel though the punch H which is the same size as the rivet head can be made of tool steel. The body of the tool is flattened out on the under side where it rests on the anvil or bench vise top and is left oval on the top. A 3/8-inch hole is drilled in the top and tool steel punches of the form shown at H may be driven in place, some arrangement being made by which the punch may be driven out and replaced by a new one if it becomes broken or by one of smaller size if different rivets are used. A hammer and an ordinary rivet set are used to set the rivets as shown in the lower portion of the illustration. Copper rivets are easily headed up and neat heads may be formed without trouble. Never use iron or steel rivets for holding brake linings in place as projecting heads may wear grooves in the brake drums. The only remedy for grooved brake drums or members that have worn thin is replacement with new ones.

CHAPTER X

WHEELS, RIMS AND TIRES

Wood Wheel Construction—Houk Wire Wheel—Dunlop Wheel—Rudge-Whitworth Wire Wheel—Solid Tire Forms—Pneumatic Tire Construction—The Cord Tire—Rims for Pneumatic Tires—Tools for Tire Repairs—How Tires are Handled—Small Vulcanizers—Shop Vulcanizing Equipment—Supplies and Materials for Tire Repair Work—How Tires Are Often Abused—Why a Tire Depreciates Rapidly—Water Rots Fabric—Tire Tube Repairs—Replacing Valve Stems—Simple Casing Repairs—Casing Repairs Made from Inside—Retreading and Rebuilding Tires—The Dry Cure Method—Air Pressures and Carrying Capacity—Increase in Pressure by Heat—Carrying Capacity of Solid Tires—Metric Sizes and American Equivalents.

THE repairing of automobile tires is work that is usually left to the specialist whereas it can be very profitably done by the average garage man if the necessary equipment is installed. The tools, supplies and apparatus needed are not expensive and the skill required is much less than that needed to do the mechanical work incidental to the repair of the engine and other vehicle parts. Before considering the subject of tire repairing it may be well to review briefly the various forms of wheels and tire retaining rims on which the tires are mounted. The tire repair processes will be considered from the point of view of those who desire to make only temporary repairs or take care of roadside accidents as well as including the more complete instructions necessary for making permanent repairs by vulcanizing processes. The equipment illustrated for doing the work is typical and has proven satisfactory in practical use.

Wooden Wheel Construction.—The most popular form of wheel to have received general application on all classes of automobiles is the wooden spoke member of the same type as used on gun carriages and for that reason termed the artillery wheel. Various steps in making the parts of the wheel and also the processes of

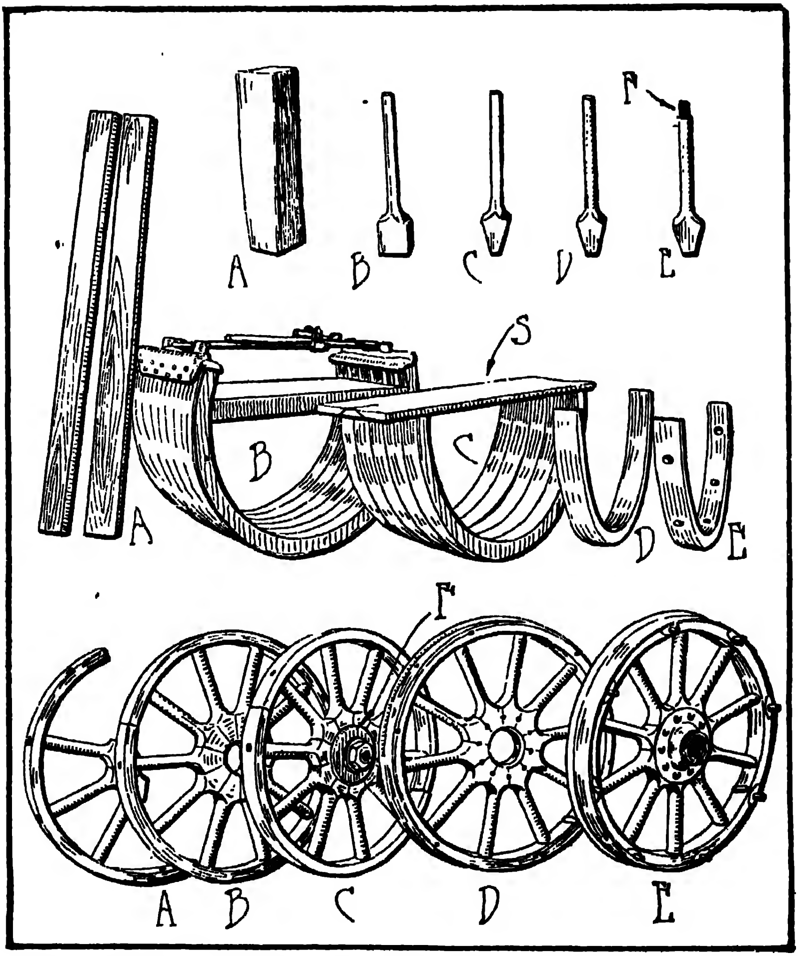


Fig. 411.—Showing Steps in the Construction of a Wooden Automobile Wheel.

wheel assembly are shown at Fig. 411. The spokes are turned from a billet as shown at A at the top of the illustration, the successive operation being shown at B in which the spoke has been turned approximately to size on a special turning lathe. The operation is called club turning because of the shape of the stock after it leaves the machine. The way the elliptical section is obtained is by having

movable centers and a cam motion to move the lathe heads in and out with respect to the cutters so as to get the section desired. The next operation is mitering down the big end as shown at C and then passing it over a planer to have the wedged shape end of uniform thickness, as outlined at D. The next step is to turn the tenon at the upper end which fits into the wheel felloe.

The felloes are made by bending special pieces of stock (which has been steamed) by a form of clamp and introducing a spacer between the two ends in order to secure the desired curvature. The bent blanks are kept in the form shown at B for a period of time and placed in drying kilns. After removal from the kiln they are held by a strip S for a time after which the strip is knocked off and the felloes sawed to the proper form. The pieces D are planed on both sides and also finished on the curved surfaces in order to smooth them, followed by an operation to drill for the spokes with a special machine. The next step is to smooth the felloe member carefully on the inside, then to sand paper off the sharp corners between the spoke holes. The felloe strips are then taken to a special machine which cuts the ends with proper relation to the spoke holes so the wheel may be assembled. The last operation is spot facing which is a form of counter boring on the inside of the felloe where the end of the spoke comes in contact with it.

The first stage in assembling the wheel is shown at A in the lower portion of the illustration. Here the spokes are driven into the felloe and when the two halves of the wheel are available they are placed in a special machine which clamps the spokes and the felloe band tightly together. While the wheel is in this machine a dummy hub is put in place and tightly clamped as shown at C. The function of this is to keep the wheel together during the assembly process. When the wheels have been clamped they are taken to an operator who cuts the joints in order to provide for the shrinking of the steel rim. The clamped wheel is taken over to a special table where the rims are placed on them. The rims of steel are heated by a series of gas flames which play upon all portions of a steel rim or band until this has been expanded enough so the wheel can be readily inserted. The rim is dropped over one of the unrimmed wheels as shown at C and placed under a heavy press

which forces the steel rim to its proper position on the wooden felloe. After the rim has been shrunk on, the false hub may be removed as the rim keeps the wheels together. The center is then bored out and a finishing cut taken on both sides of the spokes at the hub. The wheel is then carried to a drill press of the multiple spindle type which makes all of the holes for the brake drum or hub flanges. The final assembly process is to put the hub flanges in place and bolt them up.

A wooden wheel is not subject to damage or depreciation from use unless the car has skidded into a curb or hit some obstacle that will tend to knock the wheel out of true or break some of the spokes. As a rule, broken spokes can only be inserted by a wheelwright or one familiar with the manufacture of wheels. In cases where only one or two spokes are broken it is possible to insert new ones by unbolting the hub flanges and drilling out the broken end of the tenon pin that remains in the felloe. The new spokes, which may be made by hand in an emergency, are easily inserted in place of the damaged ones and the wheel assembly again clamped together between the hub flanges. In some cases, after a car has been used for a time, especially in dry sections of the country, considerable slack or looseness may exist between the hub flanges and spokes and also between the spokes themselves. No trouble will be experienced from this source if a car is washed frequently because the water will prevent the spokes from shrinking away from the hub flanges. Even if the looseness is noticeable, which is a fertile source of squeaking noises coming from the wheels while they are in service, in many cases the spokes may be swollen enough by soaking the wheel well with water to correct the trouble.

A simple method of overcoming this difficulty when the soaking treatment does not correct the fault is shown at Fig. 412. If the work is carefully done a badly racked wheel may be made capable of giving considerably more service. The hub is shown in the sketch with the flange removed to expose the mortised ends of the spokes to view. This may be easily accomplished by removing the nuts from the bolts and prying the hub flange away from the wheel. The lost motion between the spokes can be taken up by driving thin wedges of sheet steel into the open spaces though in some cases

when the spokes are very loose hard wood wedges may be driven in. In making the wedges they should be shaped straight with a short taper at the end to facilitate driving them in place. It is said that if made with a taper their full length that they will have a tendency to work out. Before driving the wedges in place they should be covered with a coating of glue and after all the wedges necessary have been inserted the protruding edges can be cut off with a chisel and the ends smoothed down flush with the spokes. Before replacing the hub flange the center of the wheel should be covered with a coat of priming paint. Obviously, the wedges should be as wide as the thickness of the spokes and only sufficiently thick to take up the space existing between the spokes. If a wheel is not very loose, wedges 1, 2, 3, 4, 5, and 6 are driven into place, though in very loose wheels another set of wedges numbered 7, 8, 9, 10, 11 and 12 should be used to fill the remaining space. It will be apparent that the bolt holes must be cleared out with a drill after the wedges have been driven in. The final operation is to replace the hub flange and bolt it tightly in position. It will be found advisable to burr over the projecting ends of the bolt after the nuts are screwed down tightly in order to prevent the nuts from backing off. The wheels of some cars are held together by rivets instead of bolts. As the heads of the rivets must be sheared off with a cold chisel to permit removal of the flange. new rivets must be in-

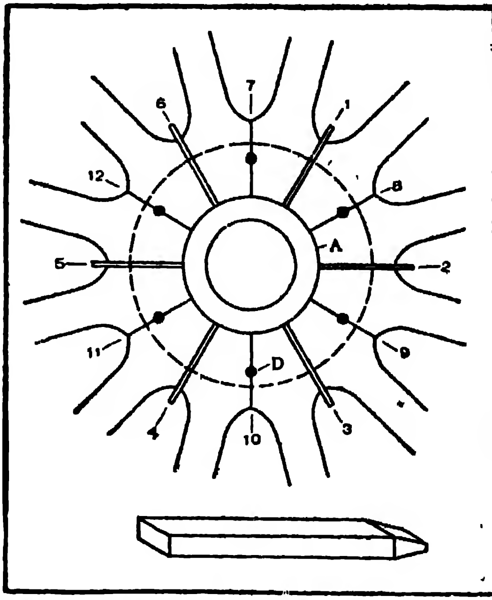


Fig. 412.—Method of Using Wedges to Take Up Looseness Between Spokes of Wooden Wheels.

serted by a process of hot riveting when the wheel is again assembled, taking care to use a rivet set in order to make a properly shaped head.

Houk Wire Wheel.—Many recent models of automobiles will be found equipped with wire wheels of some form or other. Improvements have been made in the method of lacing wire wheels so that the forms used for automobiles are very strong. This is due to a method known as triple spoke lacing as this provides a combination that permits the wheel to support radial, torsional, side thrust, and shock stresses in a much superior manner to the old double spoke lacing formerly used on light automobiles and widely applied on bicycles and motorcycles. Practically the only trouble that can occur in a wire wheel is breakage of the spokes and as most wire wheels are of readily detachable form it is only necessary to remove the defective members and replace them with new spokes, care being taken not to tighten the spoke nipple unduly and thus pull the rim out of true. The rims of the wire wheels used on automobiles are for the most part very strong and are not so likely to be pulled out of true as the lighter rims of bicycles or motorcycles are.

If a large number of spokes are broken as might result from a collision or other accident it will be advisable after replacing the spokes to true up the rim. This is done by revolving the wheel and holding a piece of chalk or crayon nearly against the wheel rim to indicate the high points where the wheels run out. These points may be eliminated by screwing in on some of the spokes and loosening on others until the wheel runs true. This requires some degree of skill but can be easily accomplished after a little practice. The spokes are usually of high tensile strength steel wire having a button head at the lower end where they fasten to the hub and a threaded upper end which screws into the nipple which draws the spoke taut and which fits in a countersunk hole in the steel wheel rim.

A typical triple spoke wheel of Houk manufacture is shown at Fig. 413, A, while the method by which it is fastened to the master hub is clearly shown at Fig. 413, B. Most wire wheels are made so as to be easily detachable from a master hub which is not re-

moved from the wheel spindle or axle and which is supported by the bearings or axle shafts. The wire wheel is built up with an auxiliary pressed steel hub as a basis which is provided with a series of holes to fit over driving pins attached to the flange of the master hub and which is formed on the inside with two tapered seats, the angle of the tapers being opposed to each other. One of the male tapers forms part of the master hub which is shown at B in place on the front wheel spindle while the other male taper is

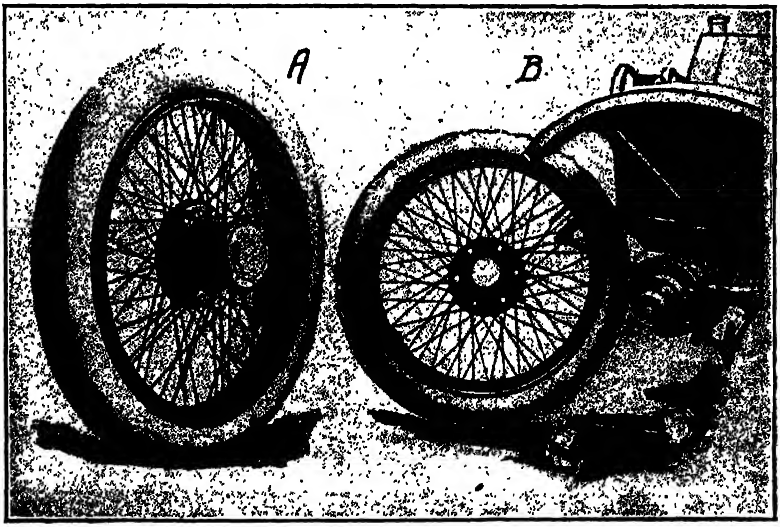


Fig. 413.—The Houk Detachable Wire Wheel.

on the locking nut. When the lock nut is screwed onto the threaded end of the master hub, which is sometimes termed the inner or fixed hub, it forces the female taper on the inside of the pressed steel wheel hub against the male taper on the master hub. The torsional force is applied to the wheel through substantial driving pins which engage with registering holes in the hub flanges.

These drive pins as well as the hub are treated with a special rust-proofing process and the pins are nickel plated, rendering corrosion or sticking of the parts difficult. If the wheels have been kept on for a time and have not been disturbed it is likely that

some trouble may be experienced due to rusting of the pins as even the nickel plating will not protect these at all times. The rust may be easily cleaned off when the wheel is removed and a repetition of the trouble avoided by greasing the pins liberally before the wheel is again replaced on the master hub. The construction of the automatic locking nut which is a feature of the Houk wheel is clearly shown at Fig. 414. The hub at A is a rear hub attached to a semi-floating drive axle while that at B shows the conventional

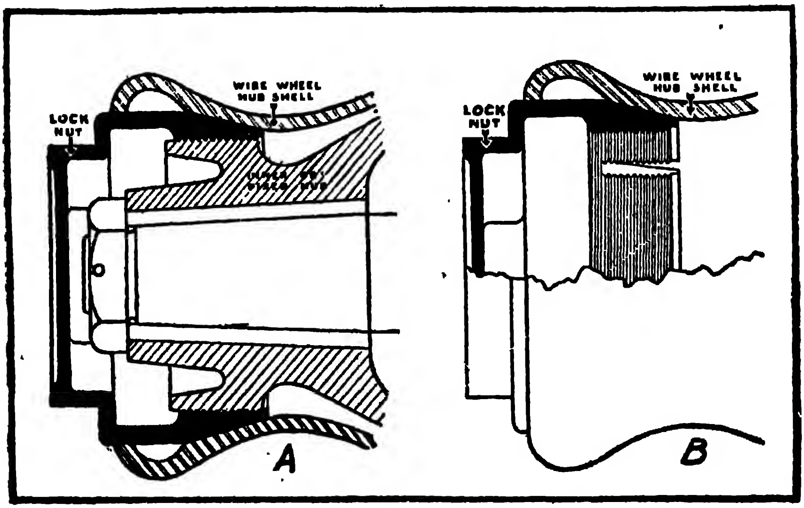


Fig. 414.—Showing the Automatic Locking Nut Employed on the Houk Wire Wheel.

arrangement for a front wheel or the hub of a full floating rear axle. These nuts are threaded for a loose running fit on the thread and have their conical end slotted into segments which allows a slight compression when forced into the conical seat of the hub shell. By virtue of the fact that the nuts are threaded loosely on the master hubs there is a difference in the circumferential length of the thread. If the nut is not drawn up tightly through neglect, the wheel supporting the weight of the car would bear upon the nut and as the wheel and hub turn when the car moves forward the nut must turn by a sort of epicyclic action which will cause the

threads to wedge together under the pressure of the load and after the manner of a cone clutch prevent slippage between the threads. This forces the nut to lag behind the angular travel of the hub parts and consequently to screw itself tighter on the threads when they are properly positioned on the car. On the right hand side of the car the hubs must be provided with left hand threads while on the left hand side the hubs have right hand threads. When the nuts are once in place there can be no creeping action, as they clamp tightly down on the main thread owing to the slight compression of the segments in the conical end of the hub.

Dunlop Wheel.—The Dunlop wheels which are shown at Fig. 415, have attained great popularity in Europe and are now being used to some extent in this country. This wheel is very quick in operation and is locked in place positively as soon as installed. The inner hubs are made of bar stock for the front wheels and drop forgings for the rear, no castings being employed. As is true of all wire wheels, the hub is composed of two pieces, one, which is a master hub intended to remain in permanent assembly with the supporting bearings while the outer or removable hub to which the spokes are fastened is readily detachable. The outer hub is prevented from turning on the inner one by serrations or teeth which are located near the conical surfaces at the inner end of the hub. These teeth are external on the inner hub and internal on the outer and are formed to fit between each other. The engaging portions of the teeth are rounded off to enable them to slip easily in mesh. A second conical surface at the outer end of the outside hub rests on the hub cap, which is locked in place in the outer portion so that it cannot drop out when that part is removed from the inner hub, but at the same time it is free to turn in order to screw on the inner portion. As the locking of the hub cap from unscrewing determines the safety of the wheel from coming off this is an advantageous point.

A cup shaped member is placed inside of the outer end of the inside hub, this is kept from turning in the hub by serrations similar to those between the two portions of the hub, but is free to slide in and out within certain limits and is normally pressed outward by a coil spring. At the outer end are more serrations, formed to fit

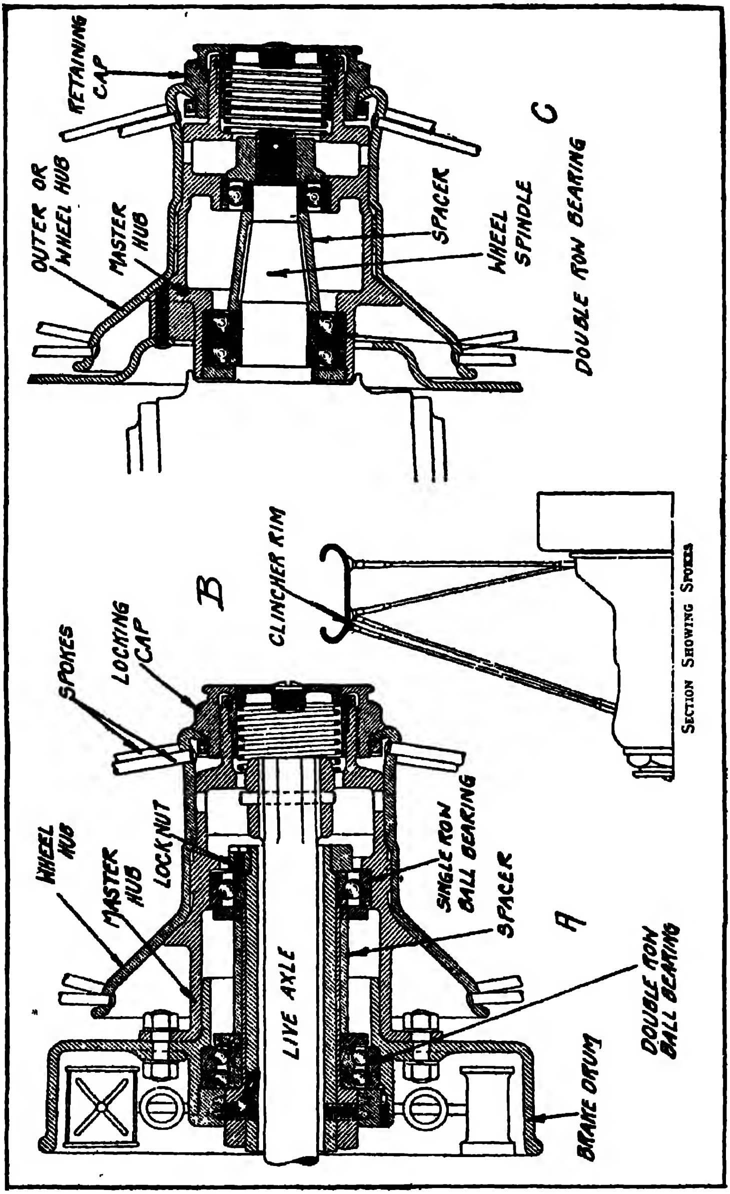


Fig. 415.—Sectional View Showing Construction of the Dunlop Quick Detachable Wire Wheel.

in corresponding parts in the hub cap. This lock is held out of engagement while the wheel is being attached or detached by an attachment to the wrench. Immediately upon the removal of the wrench it is pressed in contact with the hub cap and if not already in position to engage it will come in to the locking position if the hub cap turns one-sixth of a turn. A special wrench or spanner is needed for handling the Dunlop wheels. This is of ordinary box wrench form except that it has pawls or latches which engage in a groove at the outer end of the hub caps to hold the wrench in place and a bridge across the middle which carries a quick acting screw to depress the locking device on the inner hub. In removing the wheel the wrench is snapped in place on the hub cap and the central screw turned down to release the locking piece, which permits the hub cap to be turned off easily. In attaching, this screw should be turned down also in order to prevent the lock from taking hold before the cap is fully screwed home. After the locking cap is forced in place the lock should be released before removing the wrench and the nut turned till the lock engages so as to prevent even the slight looseness that would result if the lock slipped back into the next notch. The lacing of the spokes is in three planes like the spokes of the Rudge-Whitworth wheels which are made under the same patent. The sectional view through the end of a rear axle fitted with Dunlop wire wheels is shown at Fig. 415, A. As will be evident, the master or inner hub is carried by a combination double and single row bearing mounting, the double row form being clamped to take the end thrust on the wheel. The axle is a floating type, the bearings being mounted on the tubular housing of the live or driving axle. A similar construction is used for the front wheel which is shown at Fig. 415, C. The method of lacing is outlined at B.

Rudge-Whitworth Wire Wheel.—The construction of the Rudge-Whitworth wire wheel, which is a very popular form, is shown at Fig. 416, A, while an enlarged sectional view of the wheel hub construction is shown at B. These are triple spoke wheels consisting of a removable outer hub and a master hub mounted on ball bearings. In the illustration the permanent hub A revolves upon the plainly indicated ball bearings while B is the wheel hub. The

driving teeth or serrations are indicated at C. These are usually about ten in number to each circumferential inch. The wheel nut D is circular in form and has notches cut from its circumference to engage with projections from a special spanner when it becomes necessary to revolve it.

This nut has a locking ring L on its inner end and an angled groove N between the nut and locking ring. When the nut is re-

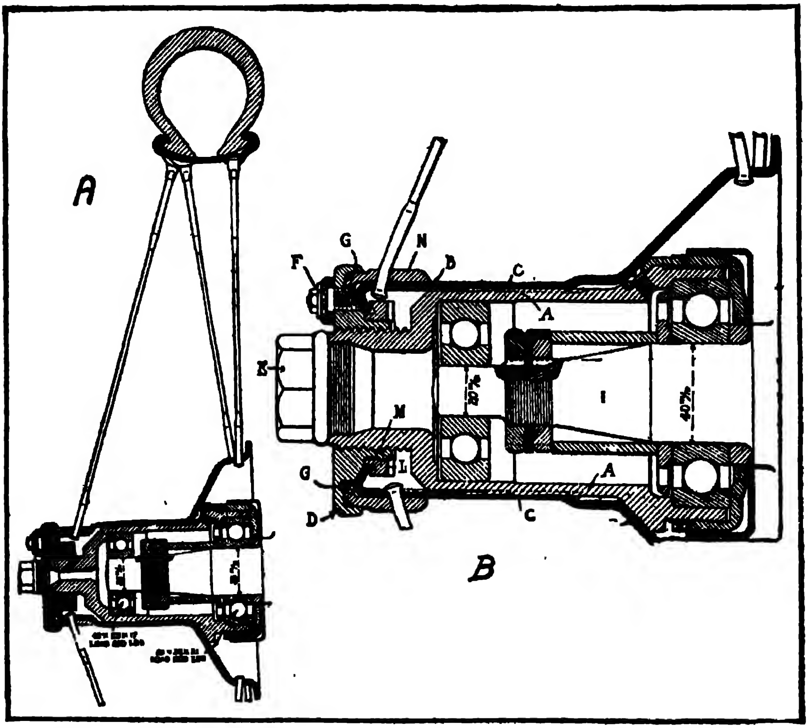


Fig. 416.—Sectional View, Showing Construction of Rudge-Whitworth Wire Wheel.

volved to the right it drives the wheel up into the permanent hub while revolution to the left withdraws it. A large screw plug E is provided for lubricating the bearings of the wheel. The locking device of the Rudge-Whitworth is said to be "meddle proof." It

will be seen that there is a steel cap M fixed on the outer end of the wheel hub and that this has a female ratchet G cut in the ends. This ratchet has to engage a pawl mounted on a small bolt well secured to the wheel nut. The pawl is kept in engagement by a spring. These parts form the automatic part of the lock. A spanner is employed to move the wheel which has an opening to suit the wheel nut but it cannot be placed thereon until a small lever which forms part of a lock is swung around so the pawl it carries engages in a depression, in which case the spanner can be easily put in position. The nut may be revolved freely until the wheel is detached. In tightening the wheel into position the spanner must be turned until the wheel is completely in place and then if the word "safe" is not exposed in the opening, a few strokes with a mallet on the end of the wrench will insure absolutely correct seating. The direction of spanner rotation should not be reversed when the wheel is being attached as this disengages the locking pawls.

Solid Tire Forms.—Practically all commercial vehicles of over 1500 lbs. capacity are equipped with solid rubber tires. A number of electric vehicles, even some forms designed for pleasure purposes are fitted with cushion tires. A number of representative forms are shown at Fig. 417. Solid tires may be of the permanently assembled or quick detachable types depending upon the preference of the truck user. The driving wheels of motor trucks are sometimes fitted with dual tires in order to secure greater carrying capacity without using excessively wide and expensive tread members. The basis of most solid tires is a ring of steel which has projecting portions to which a base of hard rubber is vulcanized. This base of hard rubber makes for secure attachment of the tire which is composed of an especially tough rubber compound. In the permanently assembled forms of tires, the metal base member is machined so that it can only be installed on the wheel rim by pressure from a hydraulic press. This means that tires can only be installed at stations where the press facilities are available. The form of tire shown at B has many advocates because it can be easily installed without expensive tools. In this form the metal base member integral with the tire has beveled edges which rest on

correspondingly beveled flange members drawn tightly in place by bolts which pass through the wheel felloe and which hold the retaining flanges firmly in place. This method of construction is a popular one when twin tires are employed as shown at B and F.

The cushion tires are usually designed to provide more resiliency than is available with the solid tires. The usual method of

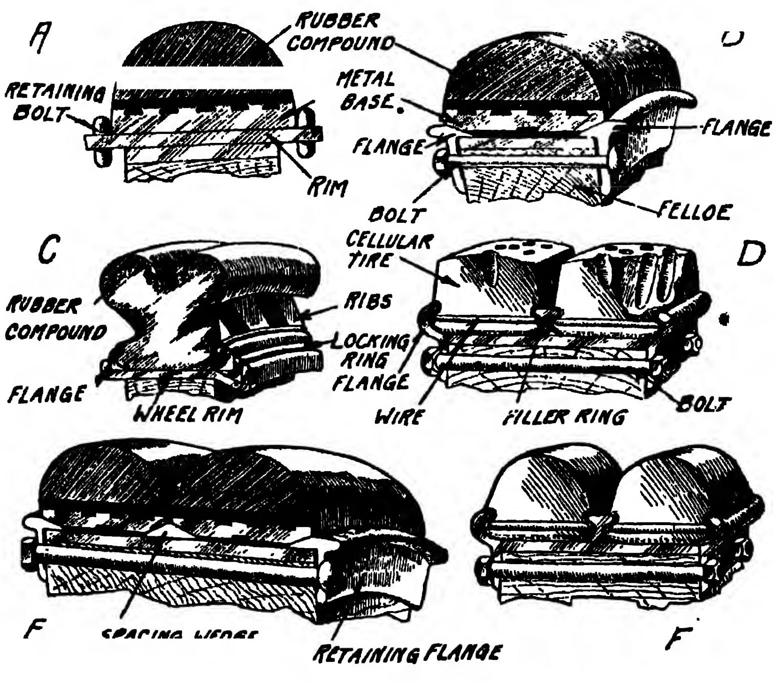


Fig. 417.—Defining Construction of Solid and Cushion Tires and Methods of Retention to the Wheel Rim.

obtaining this elasticity is to form the tread in some shape that will deflect or distort appreciably under load. The cushion tire shown at C has the tread portion supported by ribs which may give to some extent when the tire passes over a stone or other small obstruction that the solid tire will ride over. In the cushion tire shown at D, resiliency is obtained by making a large number of

holes in the tire. Repairs to solid tires can best be made at the factory where they are produced and these are seldom necessary unless the tire has been cut by accident. As a rule when a solid tire wears down the only practical remedy is to replace it, as it is not susceptible to retarding as the pneumatic tires are.

Modern Tires Are Well Made.—There is an impression obtaining with motorists, and even with many engaged in the industry, that tire expense is an element in automobile maintenance depending more upon good fortune than any care of the tire manufacturers in producing good tires, or in the motorists using reasonable judgment and care in driving, and taking precautions that the shoes will receive the same attention given other components in the vehicle. The average person, whether tradesman or layman, seldom considers the enormous stresses to which tires are subjected on even the lightest of runabouts and motorcycles, and as a general rule after shoes are fitted to the rims, they are forgotten until abuse or careless driving causes sudden end to their usefulness. Natural wear may make replacement necessary and while the American manufacturers of tires are producing types that are enduring and practical, with even the best of care the tire must eventually wear out. Some standard tires may be better than others, but all are good and will give satisfactory service if properly used. The fact that the efficient motor car of to-day would not be possible or practical without the resilient support and increased tractive effort given by the pneumatic tire is not often considered, and tires are regarded as a necessary evil, though they are really one of the most essential and hardest worked components of the motor vehicle.

It is not intended to go into the details of tire manufacture, or to compare one form with another, as the actual methods of construction are of little concern to automobilists and those in the trade; and instead of a review of the technics of tire manufacture, the writer desires to give some practical information relative to the processes of repairing tires found to be satisfactory in application, based on experience gained in both factory and shop. Such detail is seldom published and many motorists and repairmen assume that automobile tire repairing is a mysterious occupation that is beyond their comprehension. Not only among automobilists, but

throughout the greater portion of the trade as well there is no very clear conception of the processes or the careful manipulation necessary to repair tires successfully.

Construction of Tires.—While much advice has been given relative to the care of tires it will be well to speak of some causes of deterioration, and for the better knowledge of the uninformed reader the conventional methods of tire making and the qualities of the materials used are outlined. The principal materials in vehicle tires are rubber compounds and textile fabrics, and every factory has its own peculiar processes of combining these to form the finished tire. Practically all tire manufacturers procure the fabric from firms making a specialty of textile products, but generally any concern manufacturing rubber goods prefers to use those special compounds which experience has shown are best adapted for the appliances they manufacture. The basis of all tires is undeniably fabric and crude rubber, both of which are of vegetable derivation, the best fabric being of Sea Island cotton, while the caoutchouc, or India rubber, is the product of a great variety of trees, vines and shrubs, most of which grow in the torrid zone.

The substance which gives the modern tire its strength is the fabric forming a basis for attachment of the rubber, and while many materials have been tried, among them silk, wool and linen, cotton alone combines most of the required qualities. Before incorporation in tires this fabric is thoroughly dried and impregnated with rubber. Nearly all tires are formed or built on cores and are composed of layers of fabric and rubber.

At Fig. 422, A, a sectional view of a "bolted-on tire" is shown which will serve to illustrate the manner in which a tire is built of layers of materials. The outer layer is specially tough rubber, known as the tread, of such composition it is strong and specially adapted to resist abrasion, firmly attached to two layers of fabric, known as breaker strips, which rest on another layer of softer and more resilient rubber than that of which the tread is composed, termed the cushion or padding. The main body of the tire consists of layers of the frictioned or rubber impregnated fabric, the number of plies varying with the size of the shoe. In the base of the tire are incorporated hard rubber and fabric fillers to make the

structure of maximum strength. These successive layers are then put into intimate relation by vulcanization.

Cause of Deterioration.—It is evident the pneumatic tire is a combination of materials that in themselves are not specially enduring, and it is not reasonable for one to expect lengthy service from a tire. In considering the causes of deterioration we will assume the tire is a standard product of a reputable maker whose processes of manufacture eliminate defects which might result from poor material or workmanship. If the shoe is poorly made it will heat and the layers of fabric and rubber will separate, or the side walls will crack; if the wall is too thin or of insufficient strength it will blow out, tear or cut, and at the other hand if there be too much fabric used and the walls are too thick, the flexibility is reduced, the difficulty of bending under load is increased, the side walls are forced to assume sharp angles and the fabrics will be ruptured. If the tire be not properly vulcanized, the layers will loosen from each other and if the rubber compound is not right deterioration will be rapid. If the tire is cured too long its life will be short, because the process has changed the chemical composition and physical characteristics of the materials employed. It will be evident that if one regards only the product of experienced makers that faults due to poor construction and material cannot be logically considered.

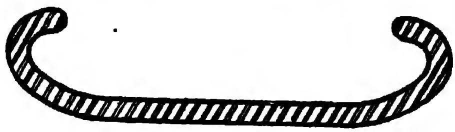
Perhaps the most common cause of tire deterioration is abuse by the user, and on the other hand there are unavoidable causes, such as punctures or hard service. Overloading and insufficient inflation are the two most common causes of poor tire service, and it is seldom that the motorist observes the most simple requirements that will insure satisfactory tire life. Each size of tire is designed by its makers to carry a certain weight which should never be exceeded, and if the weight schedule is followed in designing or equipping a car, good results may always be expected from tires, provided they are not otherwise abused. If the shoes are overloaded reasonable service cannot be expected, as no tire, no matter how well made, can continually resist the internal pressure necessary to keep it inflated enough to support the load when of insufficient capacity.

The most important advice given the purchaser of tires is to keep them properly inflated, and its value cannot be overestimated. More tires become useless from use with too little air pressure than all other causes combined, and while most drivers assume they have sufficient air in the tires they use it is a fact they habitually use tires that are not properly filled. The tire should contain air enough so that it shows but little change in form when the car is standing on a hard surface under full load, and even under these conditions it will be found that the tire is compressed considerably when the car is in action.

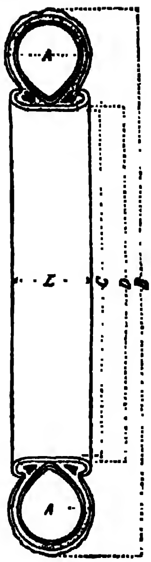
The Cord Tire.—A method of tire construction that is becoming popular because of its easy riding qualities is a difficult form to repair and is shown at Fig. 420. Instead of layers of fabric the main portion of the carcass, or casing, is composed of cores which are passed around small wires at the base of the tire and which are wound very tightly in order to secure intimate contact between the various layers of cord. Sheet rubber is placed between the cord layers and fabric breaker strips are placed between the tread and the cord body in the usual manner. When the tire is vulcanized the spaces between the layers of cord become filled with the rubber, and the whole mass is firmly bound together. The wires project into the bead portion of the tire and are vulcanized firmly in place. Owing to the construction a cord tire cannot be as easily repaired as the fabric type because it requires a very expert knowledge of cord tire construction to replace injured portions due to a blowout. As we shall see, the fabric tire may be restored to efficiency by cutting out layers of the defective fabric and vulcanizing new layers in their place. This is not a difficult operation, whereas replacing the defective cords calls for a degree of skill not usually possessed by the tire repairman.

Rims for Pneumatic Tires.—An expert has stated that there are at least forty different types of tire retaining rims that have received general application and that these require at least fourteen different sections of wood wheel felloes. Besides the various well known and popular rims a number have been designed that are more or less complicated and which are said to possess various desirable features by their manufacturers. There are six repre-

CLINCHER TIRE AND RIM DIMENSIONS



Regular Clincher Rim



A Inches	B Inches	C Inches	D Inches	E Inches
2 1/2	26	18 3/4	19	1 3/8
3	26	19 3/4	20	1 3/8
2 1/2 and 3	28	21 3/4	22	1 3/8
2 1/2 and 3	30	23 3/4	24	1 3/8
3	32	25 3/4	26	1 3/8
3	34	27 3/4	28	1 3/8
3	36	29 3/4	30	1 3/8
3 1/2	28	20 11/16	21	1 3/8
3 1/2	30	22 11/16	23	1 1/2
3 1/2	32	24 11/16	25	1 1/2
3 1/2	34	26 11/16	27	1 1/2
3 1/2	36	28 11/16	29	1 1/2
4	30	21 11/16	22	2
4	32	23 11/16	24	2
4	34	25 11/16	26	2
4	36	27 11/16	28	2
4 1/2	32	22 11/16	23	2 1/4
4 1/2	34	24 11/16	25	2 1/4
4 1/2	36	26 11/16	27	2 1/4

Fig. 418.—Standard Clincher Tire and Rim Dimensions.

sentative groups into which the various rims manufactured to-day may be classified. These are: 1. One piece clincher. 2. Quick-detachable clincher. 3. Quick detachable straight side. 4. Quick detachable universal. 5. Demountable. 6. Demountable detachable. The distinction between the two last classes is that there are a large number of demountable rims which have to be taken off of the wheel before the tire can be removed. There are others that not only have the demountable feature but from which the tire can be removed while the rim remains on the wheel.

The one piece clincher rim with its principal dimensions for various tire sizes is shown at Fig. 418. This rim is made in one-piece and not cut in any direction. It is adapted only for use with tires having soft extensible beads which can be pried or lifted over the edges of the rim. There is only one type of clincher rim on the market but at the present time its use is confined to small and medium weight cars as too much effort is needed to install large size tires on rims of this form. There are many types of quick detachable clincher rims which have been designed to make possible quick application of clincher tires which are well thought of on account of the holding power of the tire beads. These rims are invariably composed of two or three parts, consisting first of a rim base with an integral inside clinch, or separate inside endless clincher ring and a separate outside clincher ring which is made so that it may open with some fastening device for holding the ends in place or it may be made endless with an open lock ring to hold it in position.

Examples of the most popular form of quick detachable clincher rim are shown at Fig. 419. The form shown at 1-B is a type which has a base, two endless clincher side rings and an open end lock ring which may be snapped out of its seat, and permit the removal of the outside clincher ring and then the tire if it contains no air pressure. The rim shown at 2-B has the inside clinch integral with the rim base, the outside clincher ring and the lock ring being similar in action to those of 1-B though different in design. The rims shown at 3-B and 4-B are similar to rim 2-B except that the outside clincher ring is open ended having a mechanical lock for the ends of the ring. Rim 5-B has an open end outside clincher ring with an angle of the retaining groove in the rim base of such form that the inflation of the tire causes it to seat home more firmly so that no locking device is necessary.

Forms of quick detachable straight side rims are shown in this same illustration, these being very similar in construction to those previously described except that the retaining rings are made to fit straight side tires instead of clincher tires. The straight side tire, which was originated by Dunlop, has a bead devoid of any clinching arrangement though the bead is not extensible as it has a num-

ber of piano wire rings firmly vulcanized in the base portion to prevent such extension. The retaining means in the rim shown at 1-A to 4-A inclusive are practically the same as those outlined from 1-B to 5-B inclusive. A number of combination rims has been

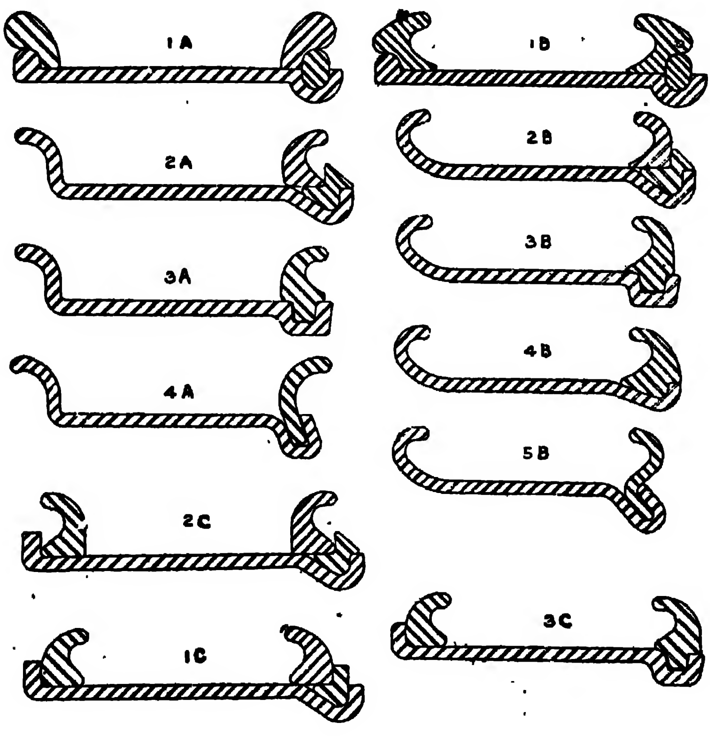


Fig. 419.—Sectional Views, Showing Construction of Quick Detachable Rims that Have Received Practical Application.

devised which can be adapted to take either straight side or quick detachable clincher by merely reversing the retaining rings which have a section adapted for retaining either the clincher bead or the straight side form. These are shown at Figs. 1-C to 3-C, inclusive.

Examples of quick detachable demountable rims are shown at Fig. 421, A. As will be observed these are rims of the simpler

form having tapering flanges on the base by which they are held to the wheel felloe by suitable wedge rings or clamp nuts. Demountable rims are shown at B. These are adapted to receive the standard clincher rings as shown in the upper portion of the illustration or the one piece straight side Dunlop rim as shown in the lower part of the illustration. As will be apparent the rims are held in place by a series of wedges which are forced in the space between the tire carrying rim and that attached to the wheel

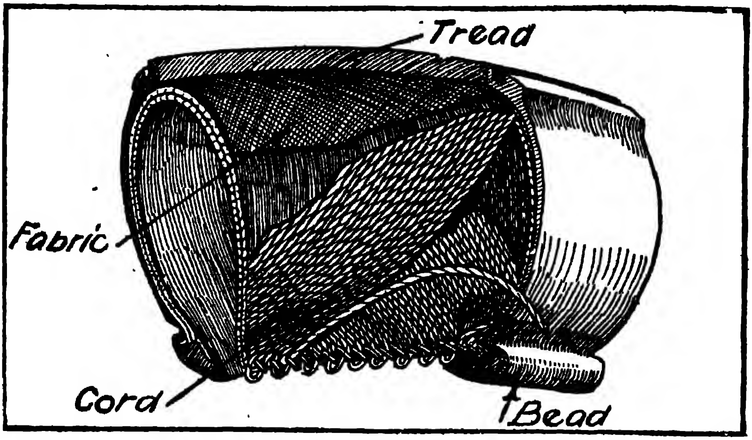


Fig. 420.—Sectional View, Showing Arrangement of Cords that Replace the Fabric Carcass in the Palmer System Cord Tire Construction.

felloe. A form of tire retaining rim that was formerly very popular is shown at Fig. 422, A. This is known as the Fisk Bolted-On type and could only be used in connection with a tire having a base of the form shown in the illustration. The tire was securely held to the steel rim by means of retaining rings which were clamped firmly in place by bolts carrying specially formed washers designed to clamp over the edge of the retaining ring as well as that of the rim. When it was desired to remove the rings the special tools shown at Fig. 422, B, were needed. The special clamping member was used to squeeze the rings closely together and permit screwing up the retention nuts with the special socket wrench provided for the purpose. When the retaining bolts had been un-

screwed all the way around the tire the rings could be withdrawn and the tire easily pulled off of the flat rim. When the tires were installed the clamping member came in handy to squeeze the rings and the portions of the tire base closely enough together so the nuts could be caught on the end of the bolts.

The Goodrich quick detachable rim and the special tool needed for its manipulation are shown at C. The feature is in the shape of

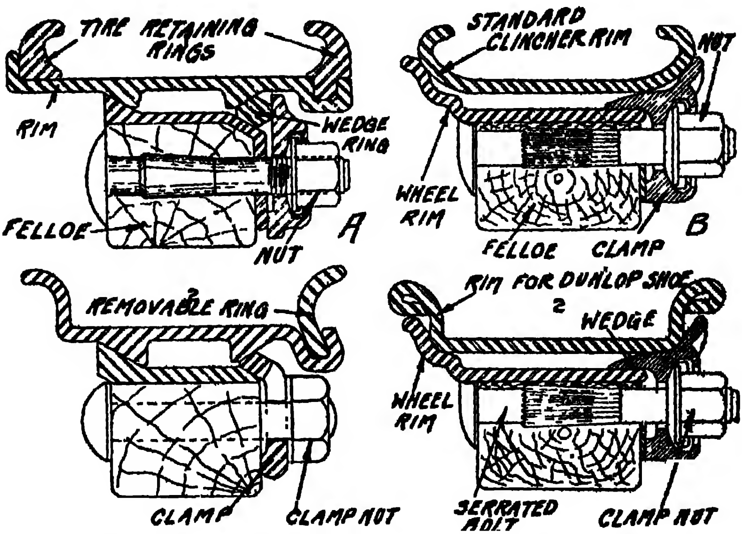


Fig. 421.—Sectional Views, Showing Construction of Quick Detachable Demountable Rims.

the locking slot in the rim attached to the wheel felloe. The open end locking rim carries tongues which fit into the slot and which may be sprung into place to securely lock the rim. The tool shown is provided to facilitate bringing the end of the locking rings together in order to spring the tongues into the locking grooves. The pins in the ends of the levers fit suitable pin holes in the locking member. When it is desired to remove the ring one of the tongues is pried out of its locking groove and then pulled away from the rim at all points. After the ring has been partially detached it is

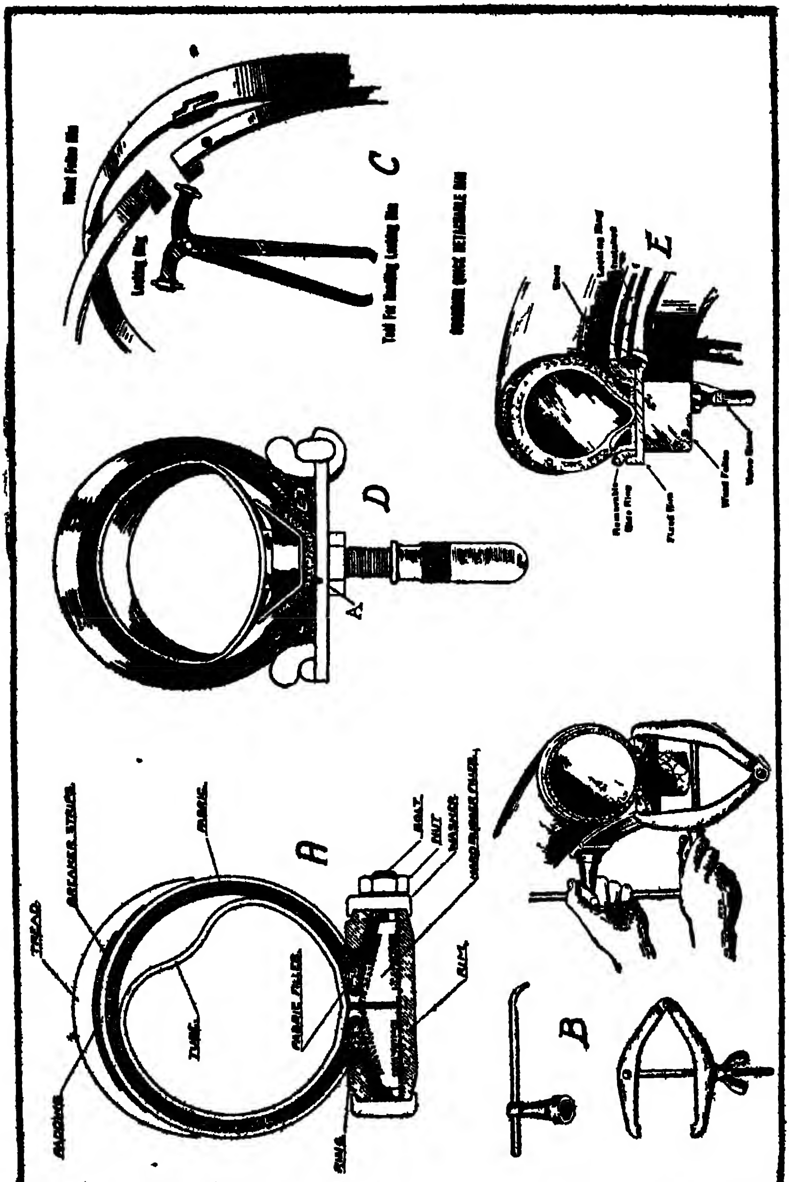


Fig. 422.—Views Showing Construction of Various Types of Quick Detachable Rims and Tools for Their Manipulation

not difficult to remove the remaining tongue from the wheel felloe rim. When replacing this locking ring, the first step is to catch the tongue on one end of the ring under the wheel felloe rim by inserting it in the notch nearest the edges of the rim. The ring is then forced in place all around and finally locked by bringing the remaining tongue in the groove nearest the center of the wheel and then springing that in place over the projecting portion near the edge of the rim. The method of installing a straight side tire when a rim of the form shown at Fig. 419, 1-A, is used is clearly shown at Fig. 422, D and E. The section at D shows the method of installing the spreader member at the base of the valve properly while the general application of the locking ring may be clearly ascertained at E.

Tools for Tire Repairs.—It is necessary in all cars using pneumatic tires to carry a certain amount of equipment for handling and repairing these on the road. A typical outfit is shown at Fig. 423, this supplementing two spare outer casings, and two or more extra inner tubes for replacement purposes. Included in the repair outfit are a blowout sleeve, a number of patches, and an acid-cure vulcanizing outfit for applying them. Tire irons are provided to remove the casing from the rim; the jack is used to raise the wheel of the vehicle on which the defective tire is installed from the ground and make it possible to remove the tire completely from the wheel. The air pump is needed to inflate the repaired tube or the new member inserted to take its place. Talcum powder is provided to sprinkle between the casing and the tube to prevent chafing or heating, while the spare valves and valve tool will be found useful in event of damage to that important component of the inner tube. As it is desirable to inflate the tires to a certain definite pressure, a small gauge which will show the amount of compression in the tire is useful.

The outfit shown may be supplemented by other forms of vulcanizing sets and by special tire irons to make for easier removal of the outer casing. Tire irons vary in design, and most makers of tires provide levers for manipulating the casings, which differ to some extent. A set of tire irons such as would be needed with a clincher tire equipment could be selected from the forms shown

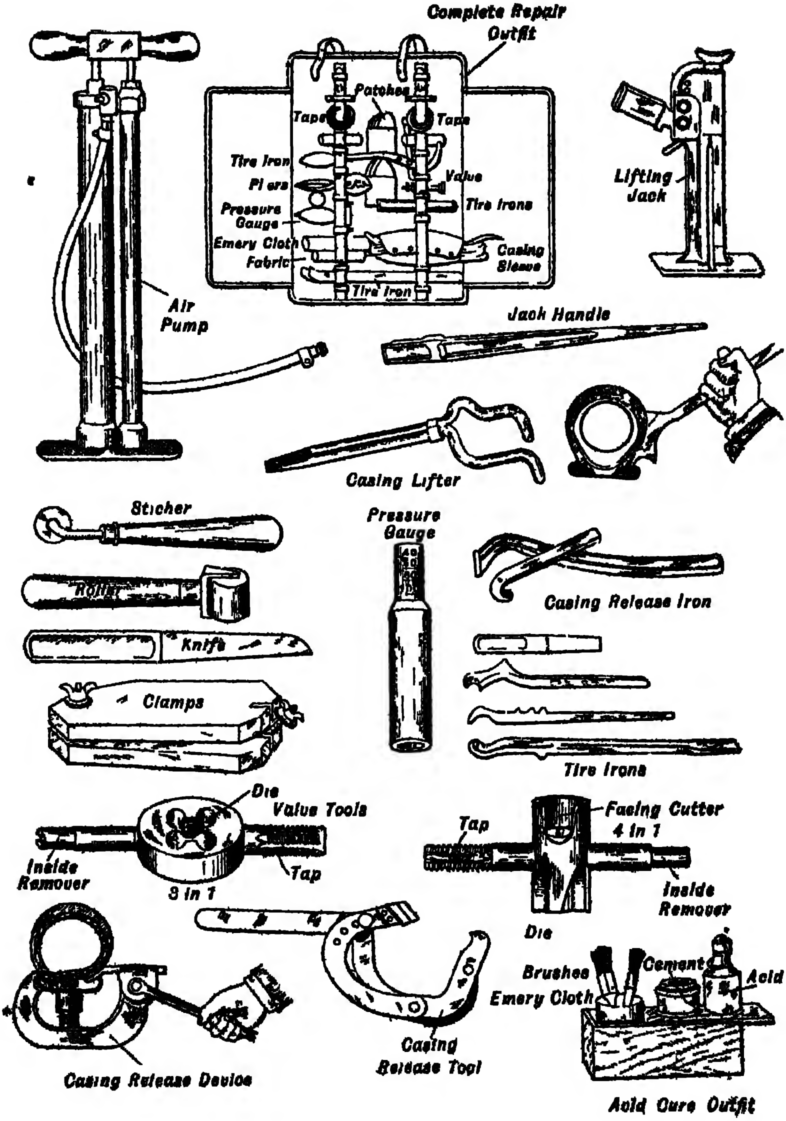


Fig. 423—Tools and Supplies for Pneumatic Tire Restoration.

at Fig. 423. That shown near the gauge is utilized to loosen the clincher bead from under the rim should it become rusted in place. After the shoe has been loosened from the rim flange, levers of the form shown below it would be inserted under the bead in order to lift it over the rim. Two or more of these levers are necessary, the long ones being more easily operated than the short ones. The length of the lever provided will depend entirely upon the size of the tire to be removed. Motorists, as a rule, should carry one of the releasing levers shown, two of the short members depicted and one longer lever. The latter may be a combination form which can be used as a jack handle as well as a tire iron, and then it is not necessary to carry a jack handle in the equipment. The flattened ends are generally employed for prying the bead from the clincher rim, and when this has been done and sufficient space exists between the bead and the rim to insert the curved end of the large levers, considerable leverage is obtained and the bead may be lifted over the clincher rim without undue exertion. The object of rounding the corners, and of making the working portions as broad as possible is to reduce the liability of pinching the inner tube, which would be present if the irons had sharp edges.

The tire repair material is sometimes carried in a special case, as shown at top of Fig 423, this consisting of all parts necessary to make temporary repairs to be considered in proper sequence. This outfit is sometimes supplemented by other special tools. A knife is needed to cut the rubber, trim patches, etc. The stitcher and roller are useful in rolling the patch after it has been cemented to the tire to insure adhesion of the patch firmly against the damaged portion of the tube while the cement is drying. Some motorists carry a small flame heated vulcanizer in order to effect more permanent repairs than would be possible with the simple patching processes in which only the adhesive powers of dry cement are available.

Portable Air Compressor.—Some Locomobile cars are equipped with a single cylinder air compressor, having a bore of 2½ inches, and a stroke of 2½ inches, which may be considered typical of such devices which are often included on recent models of leading cars. It is mounted on an extension of the front end of the transmission

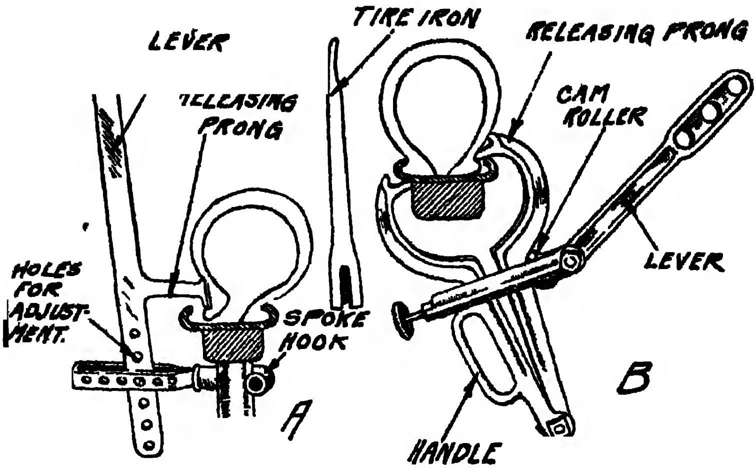


Fig. 424.—Tools for Releasing Clincher Tires When Beads are Rusted in the Rim Channels.

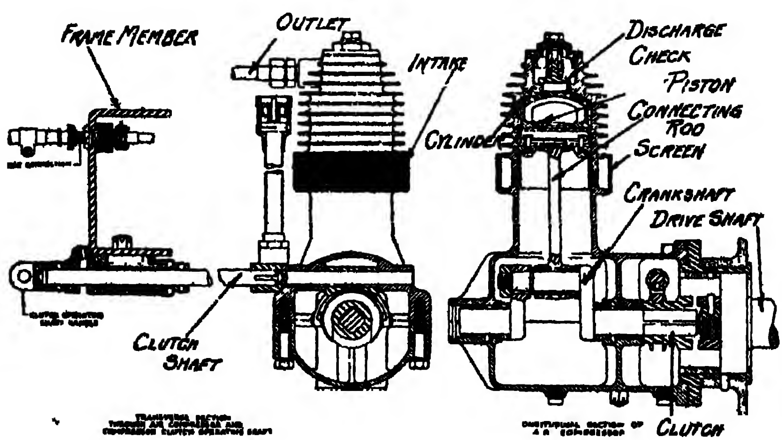


Fig. 425.—View Showing Construction of Small Air Compressor Used on Locomobile Cars for Tire Inflation.

countershaft, and driven by means of jaw clutches, which can be thrown in and out of engagement by a T handle located on the left side of the car, and reached by opening a door in the running-board side shield. By drawing handle outward about 3/16 of an inch, advancing one notch to the left in a serrated segment and releasing, jaw clutches are interlocked and pump is ready for use. Air is drawn into the cylinder through holes drilled around same below radiating fins. Foreign matter is excluded by means of a removable screen. On the upper stroke of the piston the air is forced out of the cylinder by unseating a flat valve into a small tank placed at the right of the air compressor, and mounted in front of the transmission carrying channel. The purpose of this tank is to overcome the pulsation of the pump only and not to act as a reservoir.

By means of a two-way fitting air is drawn out of the tank through a delivery tube leading to a fitting which projects through the left side member of the frame adjacent to the T handle mentioned above. One end of the tire hose is screwed on to this fitting when tires are to be inflated. The location of the two-way fitting on the tank is such that any sediment or oil falls to the bottom of the tank, and is not drawn out through the delivery tube. With the motor running at normal speed the air compressor will inflate a 37 x 5 inch tire to 90 pounds pressure in about two minutes. Every 2000 miles, or oftener if the compressor has been used frequently, the oil in the crank case should be replaced. The crank case is drained by removing a plug located on the bottom. To fill, remove both the large and small plugs on the left hand side, and pour oil through the larger hole until it overflows through the small hole. In case the oil which was removed seems especially dirty, fill the crank case with kerosene and drain before putting in new oil. This compressor is clearly shown in Fig. 425.

Tire Manipulation Hints.—In removing or replacing outer casings, considerable care must be exercised not to injure the shoe or pinch the inner tube. The first step is to jack up the wheel from which the defective tire is to be removed, thus relieving the wheel of the car weight. The valve inside is then unscrewed in order to allow any air that may remain in the tube to escape, and then the

lock nuts on the valve stem are removed so that this member may be lifted to release the clincher beads from the rim channels. If the tire is stiff or has not been removed for some time, a special iron is utilized to loosen the edges and the beads are pushed clear of the clincher rim.

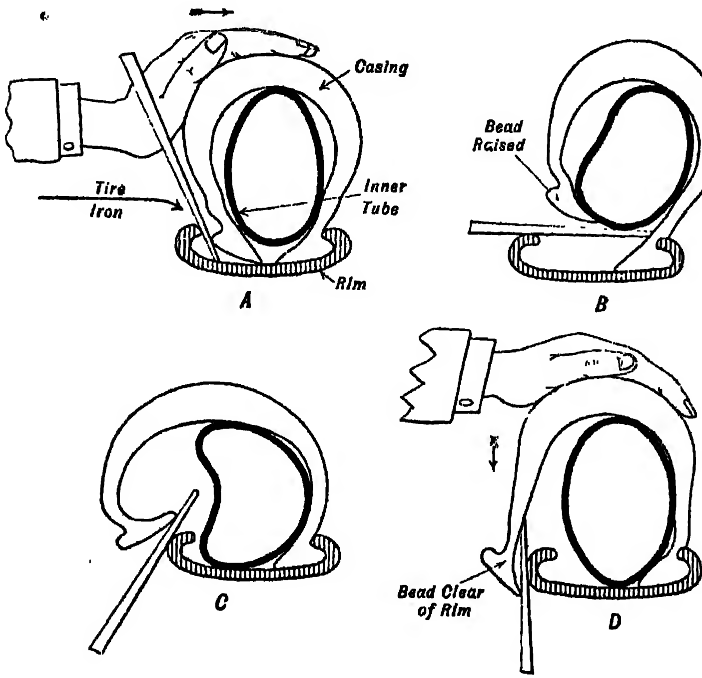


Fig. 426.—Defining Manipulation of Clincher Tires.

When the casing has been loosened on one side, a flat tool, as shown at Fig. 426, is inserted under the loose bead to act as a pry or lever to work the edge of the casing gradually over the rim. Very long levers are necessary to handle new stiff tires, and unused casings are particularly hard to move. The shorter irons may be employed on shoes which have been used for some time and which are more pliable than the new ones. Two of the levers are

generally used together, one being kept under the loosened edge of the bead, while the other is used to force the bead over the edge of the rim. When the outside edge of the bead has been forced over the rim at all points the inner tube is lifted from the rim and is pulled out of the shoe. The start at removing is made at the point diametrically opposite the valve stem. When this portion has been pulled clear of the rim and out of the casing it is not difficult to pull the rest of the tube out and finally lift the valve stem out of the hole through which it passes in the wheel felloe, and take the inner tube entirely off the wheel. If the casing demands attention, or if a new shoe is to be used, the inside bead is worked over the channel of the clincher rim in just the same manner as was done with the outside bead, and after a start has been made and a portion of the inside bead forced over the rim there will be no difficulty in slipping the entire shoe from the wheel.

Applying a tire is just the reverse to removing one. The first operation is to place the inner bead of the tire in place in the center of the rim by forcing it over the outside flange. This is done gradually, and in order to force the remaining portion of the shoe it may be necessary to use long levers when the greater part of the casing has been applied. The next step is to work the shoe gradually toward the inner channel of the rim, then to insert the air tube. The inner tube is replaced after it has been partially inflated by putting the valve stem in first and then inserting the rest of the tube, being careful not to pinch it under the beads.

After the inner tube has been put in place, the outer bead of the tire is worked over the edge of the rim channel. Care must be exercised to insure that the inner tube will not be pinched by the sharp edges of the tire levers. The object of partially inflating the inner tube is to distend it so there may be no loose or flabby portions that are liable to catch under the tire bead when this is being forced in place over the wheel rim. The conventional method of inflating tires by using a foot pump does not always insure that they will receive adequate inflation, and when a pump is employed it is imperative that some form of gauge be provided that will register the amount of pressure inside the tire in order that it will reach the figure recommended by the tire makers. Different meth-

ods of tire inflation have been devised which eliminate the necessity of using manually operated pumps. Obviously a simple expedient would be to provide a small power-driven pump that could be actuated by any convenient mechanical connection with the engine or a spark plug pump. Another method is to use an air bottle, which is a steel container in which air is stored under great pressure. The air is compressed to such a point that a tank less than two feet long and six inches in diameter will furnish sufficient air to inflate seven or eight large tires or twelve small ones. The tanks may be exchanged at small cost when exhausted for new containers holding a fresh supply of air. In some tanks, gases of various kinds under high pressure are used and the motorist may obtain these on the same basis as air bottles are supplied.

All devices of this character are fitted with gauges to indicate the amount of pressure in the tire, and to prevent overinflation. If a tire is not properly inflated the shoe will be liable to various kinds of road damage and will be easily punctured, while if the pressure is too high the shoe is liable to "blow-out" at any weak point in the structure. A tire-pressure gauge is a very necessary article of equipment in any car and its proper use when blowing up tires will insure the best possible results if the schedule recommended by the tire manufacturers is adhered to. Three inch tires should be inflated to 60 pounds, and three and one-half inch to 70 pounds pressure. The rule is approximately 20 pounds for every inch of tire width.

Small Vulcanizers.—A number of portable vulcanizers designed for the use of the motorist so that tires may be repaired without removing the casing from the wheels if surface cuts are to be vulcanized is outlined at Fig. 427. These operate on three different principles, some depending on the heating effect of coils conveying an electric current, others upon steam produced by a small burner acting upon the water contained in the casting while the simplest form utilizes dry heat produced by burning gasoline in the vulcanizer. The form at A obtains its heating property from steam and is shown clamped in place to seal a cut in the casing. The form at B is heated by electric current and is also shown clamped to an outer casing. The form at C derives its heat from the flame

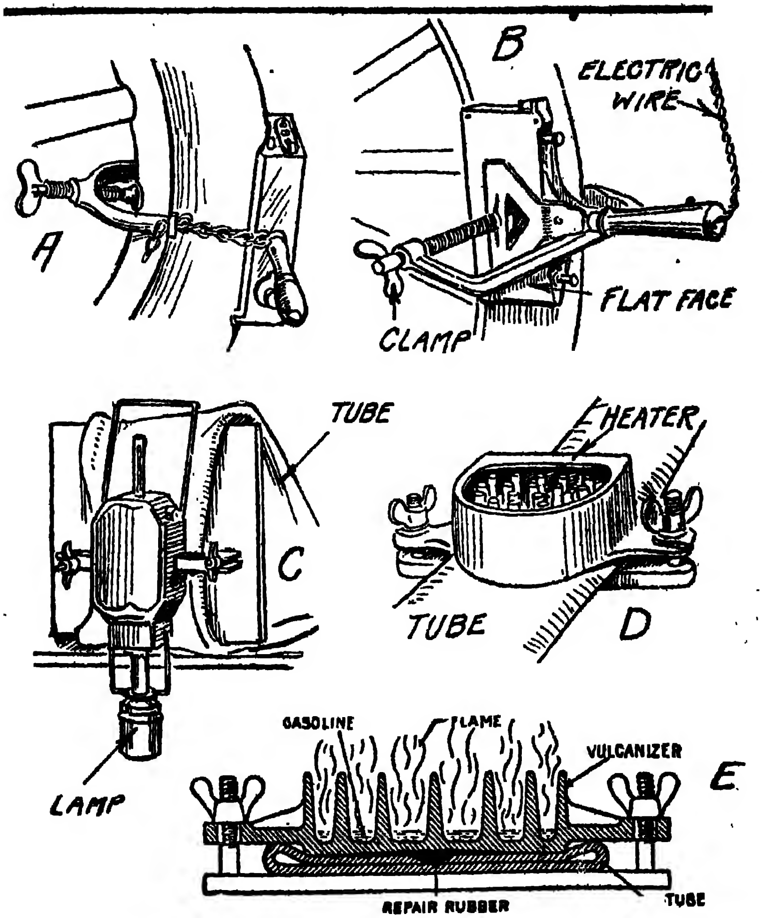


Fig. 427.—Views Showing Small Portable Vulcanizers Suitable for Road or Shop Repairs.

of a small lamp burning alcohol or gasoline which heats water contained in the body of the device. This has two faces, one flat for use in vulcanizing patches and inner tubes as shown, while the other is curved to permit it to make repairs on outer casings. The form at D is used only for inner tube work and the method of

action may be readily understood by referring to the cross section at E. The heating portion consists of a simple casting having a number of projecting fingers which are heated by the flame of burning gasoline. A definite amount of fuel is poured into the heater and ignited and after this has burnt itself out enough heat will have been imparted to the casting to produce satisfactory vulcanization of the repair material placed in the defective portion of the inner tube. These small vulcanizers are intended primarily for the use of the motorist in making minor repairs and are not practical tools for the tire repair shop, though they may be used to advantage in small garages where no attempt is made to carry on tire repair work on a large scale. Under these conditions they will prove practical in coping with the various emergency repairs such a garage may be called upon to perform.

Shop Vulcanizing Equipment.—There is considerable difference between the vulcanizing equipment intended for the use of the average motorist or small repair shop and that intended for commercial work. Whereas the small vulcanizers are usually intended for curing but one tube patch or casing patch at a time the large ones have provision for treating a number of tubes and casings at one heat simultaneously. Practically all of the commercial vulcanizers operate by steam. This is generated in a small boiler and is led to the various molds and plates for curing the inner tubes. A steam gauge is provided as the temperature of the steam may be readily determined by its pressure and in some cases a safety or blow off valve is provided to prevent the generation of too much steam.

A typical vulcanizing outfit having a capacity for curing three inner tubes and two casing sections is shown at Fig. 428. The tubes are cured on a flat plate which is at the top of the boiler while the steam for curing the casings is led to the hollow mold carried by the table. A gas burner is provided to produce the heat necessary for turning the water contained into the boiler to steam. Valves are placed in the various steam lines in order that the flow may be controlled. A group of vulcanizers of various patterns is shown at Fig. 429. The feature of the Shaler automatic plant shown at A is a machined surface 4 x 30 inches which will vul-

canize six tubes as easily as one. It can be heated independently of the casing attachment or used simultaneously with it. In the vulcanizing outfit shown at Fig. 428, pressure is applied to the patch by means of coil springs, whereas in the Shaler, the pressure to secure intimate adhesion is applied to the tubes by means of swivel clamps which produce a uniform pressure on every part of

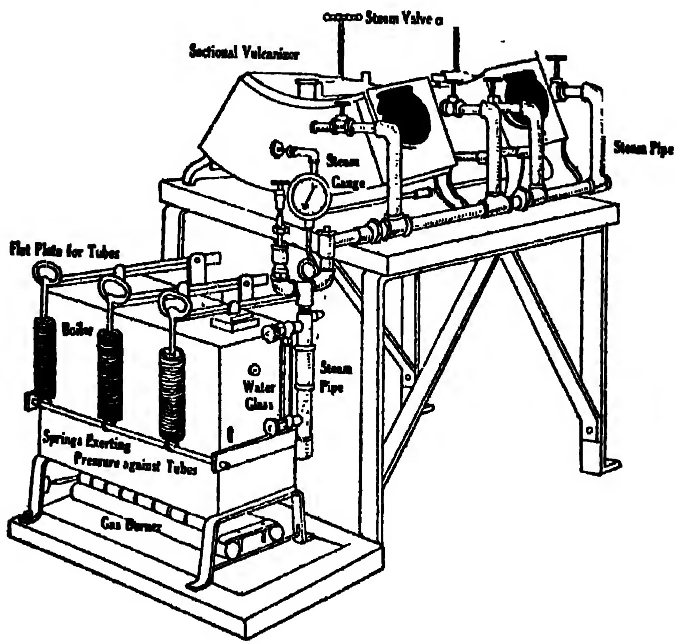
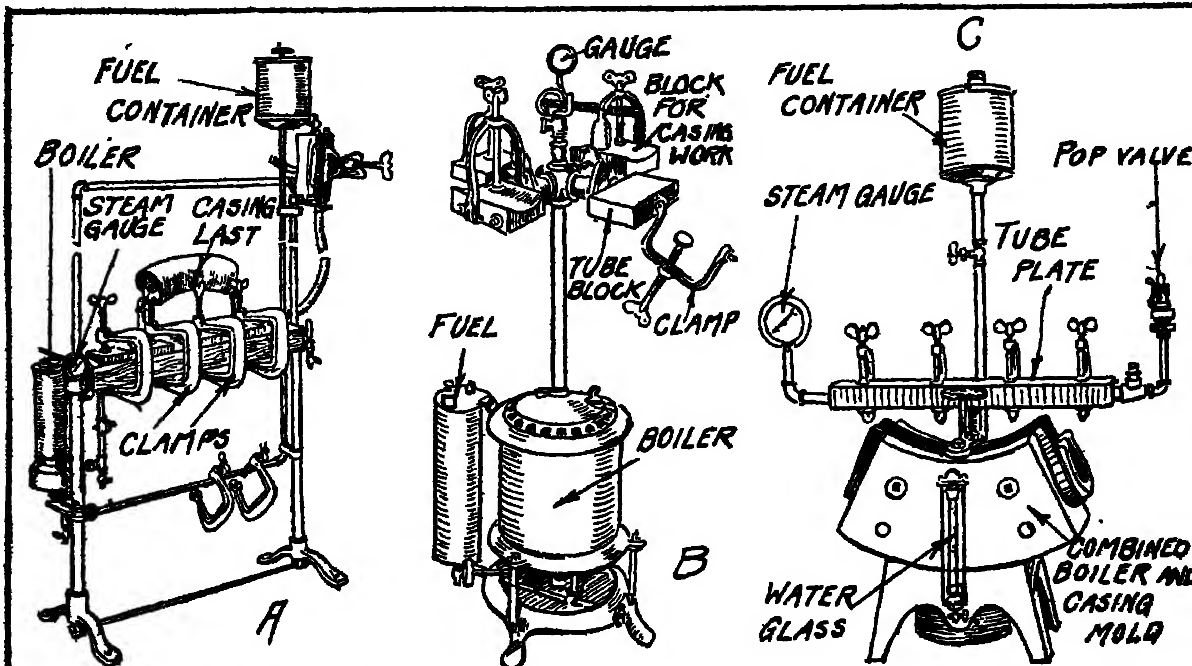


Fig. 428.—Typical Shop Vulcanizer.

the patch. With this outfit the method of making blowout repairs is by curing from the inside with the inside casing mandrel and from the outside with the casing tread form simultaneously. Instead of cutting away a quantity of rubber and fabric, a reenforcement of heavy fabric is built up inside of the casing and the holes through the rubber are filled with pure Para gum. The boiler is a copper coil heated by a powerful gasoline burner which



SHALER AUTOMATIC PLANT — RADIUM GARAGE OUTFIT — MILLER GARAGE VULCANIZER

Fig. 429.—Steam Heated Vulcanizers Suitable for Commercial Repairs of Pneumatic Tires.

raises steam to the vulcanizing pressure from cold water in fifteen or twenty minutes. A thermostatically controlled damper maintains the pressure and temperature of the steam at the correct vulcanizing point automatically. The "Radium" outfit which is shown at Fig. 429, B, is provided with two tube blocks and two casing blocks, these coming from a globe fitting carried at the end of the steam pipe leading from the boiler. In the Miller garage vulcanizer which is shown at Fig. 429, C, the casing mold is combined with the small boiler while the tube plate which has provision for vulcanizing four tubes at a time is mounted above the casing mold. Attention is directed to the accessories, these including the steam gauge at one end of the tube plate, the safety pop valve at the other and the water glass to indicate the correct level of water at the front of the combined boiler and casing mold.

The outfit shown at Fig. 430 is of Haywood design, and is known as the "Hoosier" plant. It is not intended for retreading work but for sectional and inner tube repairs. It is a compactly built equipment with a boiler containing two vertical fire flues capped with a baffle plate to hold the heat down. A steam conducting pipe leads from the boiler to the steam dome, this having four outlets which lead to the several molds. All molds are of a shape that is self-drained and condensation returns back through the steam supply pipe. It is said that this plant will cure all types of casings ranging in size from 2½ to 5½-inches, that it will cure a blowout up to 15 inches in length and will even cure a tire cut from bead to bead. The tube vulcanizing plate is of ample size and will cure three or four inner tubes at one time.

The various types of molds and the method of using them are clearly shown at Fig. 430, these being intended for use with the vulcanizing plant depicted at the left of the illustration. As will be apparent the mold proper consists of a hollow casting shaped to conform to the tread of the tires it is to fit at the bottom and having smoothly planed side walls to insure a correct fit of the bead molds as the fit determines the amount of heat conduction and the successful curing of the entire injured section of the casing. The mold is shown at 1 while the arrangement of the mold bead form and clamp is clearly outlined at 2. Bead molds are made in various

patterns, those at 3 and 7 being intended for straight side casings while the forms outlined at 4, 5, and 6 are for use with clincher casings. The air bag which is placed inside of the tire casing in sectional work with the usual process of vulcanizing is shown at the

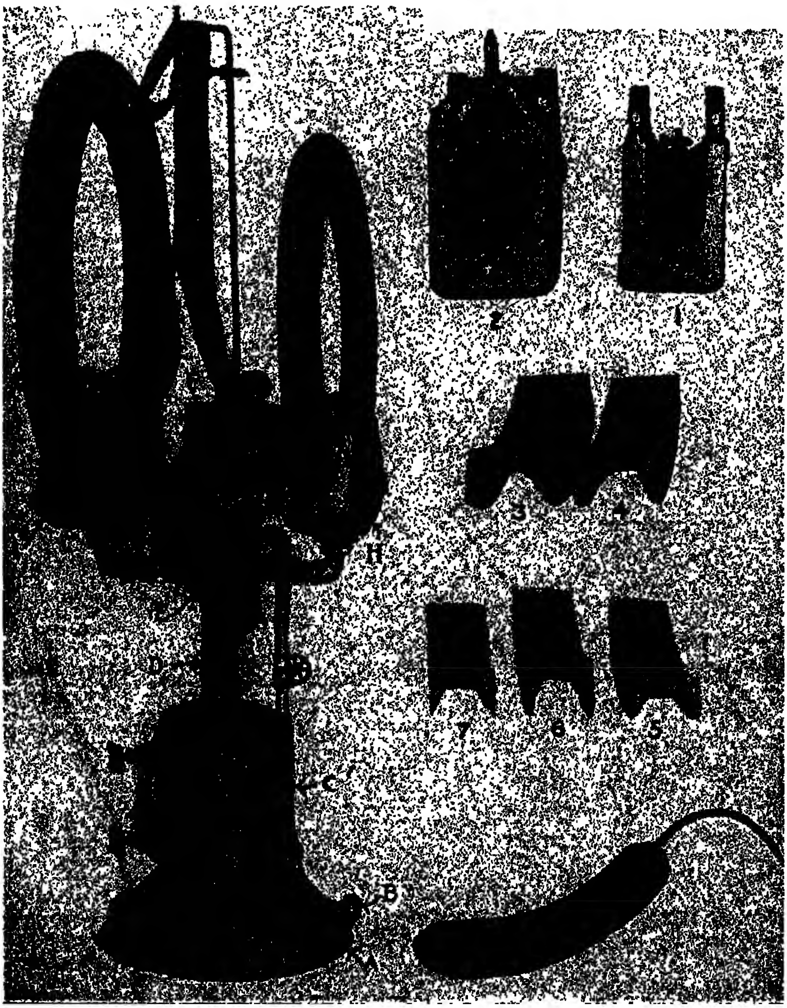


Fig. 430.—The Haywood "Hoosier" Vulcanizer and Sectional Molds for Same.

lower portion of the illustration. This is practically a short section of heavy wall inner tube provided with an inflating tube and valve in order that it may be blown up when placed inside of the casing to press the sides of the casing firmly against the heated walls of the mold. The mold is heated by the steam circulating through the hollow interior while the bead molds are raised in temperature because they are in contact with the heated walls. The clamp serves to keep all parts in secure engagement and makes

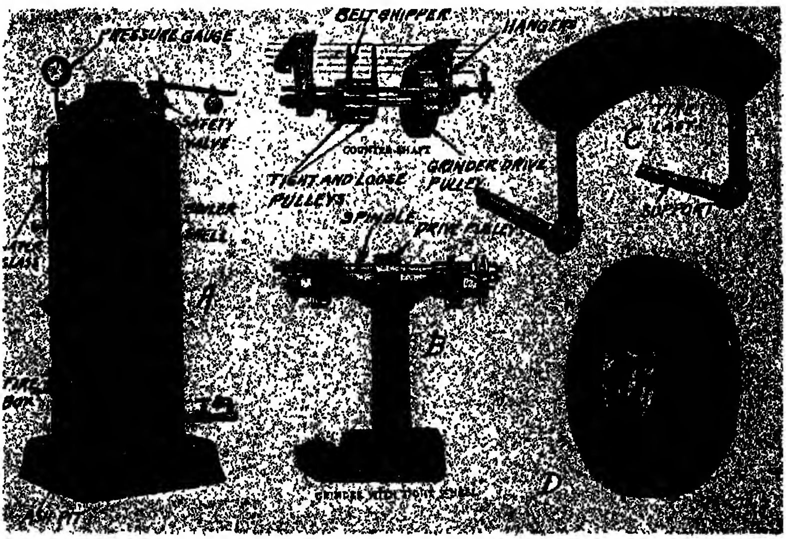


Fig. 431.—Some Useful Accessories for the Tire Repair Shop.

for uniform heating as well as providing a degree of pressure which is very desirable in vulcanizing.

In some cases the vulcanizing molds are placed on a large table and the steam is obtained from a boiler of larger capacity than those ordinarily supplied with the vulcanizers previously described. In a large shop where much tire repairing is done the small vulcanizers will not have sufficient capacity so a large number of molds and tube vulcanizing plates are arranged so they may be supplied with steam from a large separate boiler. This is coal fired for the most part and as will be evident by referring to Fig. 431, A, it fol-

lows the conventional design of the vertical fire tube boilers used in making steam for engines and heating purposes. There is a number of supplies that can be included in the shop's equipment to facilitate the repair processes. Where much tire repairing is done the grinder and countershaft shown at Fig. 431, B, will be found valuable because of the ease with which worn rubber may be ground off of a casing and also because of the advantage obtained by roughening the rubber and fabric with a wire scratch brush as shown at D in order to remove all dirt, grease, etc., and make for positive adhesion of the cement. The tire last shown at C is intended to be attached to the work-bench by simple iron pipe supports for working on casings, as it provides a secure resting place when stripping down layers of fabric in making sectional or other repairs. Some systematic method is necessary to take care of the material in process of repair. A simple tire rack for holding casings is shown at Fig. 432. This is very easily made, and obviously the design may be varied from that shown to provide accommodations for inner tubes as well as casings, the basis of the stand of rack consists of standard iron pipes attached to the floor and ceiling, the tires being supported by wooden strips attached to brackets clamped to the iron pipe. The

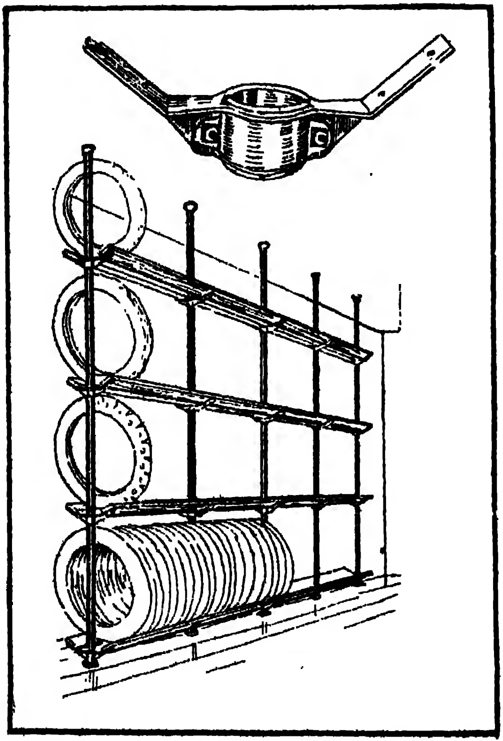


Fig. 432.—An Easily Constructed Tire Rack.

brackets are simple castings and may be moved up and down to accommodate different size casings by releasing the clamping screws, and they are easily locked in position at any desired point on the pipe by tightening the clamping screws.

Materials Employed in Tire Work.—The stocks and compounds commonly used in tire repair work are many and as is true of other forms of construction, none but the best should be employed. Many tire repairmen use cheaper grades of stock because the margin of profit is larger, but this is poor policy, and any one who wishes to establish a business will find that only the best selected material should be employed. If this is bought from reputable makers, at a fair price, there can be no question as to quality. Cover stocks are used for retreading and padding, and vary in composition and gauge from $\frac{3}{64}$ to $\frac{3}{32}$-inch thickness to meet different requirements. Some retreading stock is in the form of thin sheeting, other forms, known as "camelback," are calendered thick in the center so that it answers the same purpose as though several layers of the regular retreading stock were used. "Inside patching" is a rubber stock cured on one side and uncured on the other, made especially for repairing tire tubes. Frictioned fabric is a textile product of high grade long fiber cotton, impregnated with rubber composition, while rebuilding fabric is frictioned material having a skim coat of pure gum in addition. "Bareback" fabric is material frictioned on one side only, while breaker strips are narrow widths of frictioned fabric in various sizes, ready for application to tires without cutting, save for length.

When an inner tube is blown out badly it is necessary to cut it at that point and use what is called a tube splice, this being made with a short piece of tubing with each end tapered that joins the ends of the ruptured tube. Cements vary widely but should always be similar in composition to the rubber upon which they are to be used, as to make a good joint by the vulcanizing process the cement should contain the same percentage of sulphur. This is another condition in which the experienced man scores, as if care is not taken in the selection of the cement, very unsatisfactory results are obtained in vulcanizing. Most rubber cements consist of pure Para rubber dissolved in naphtha or other solvent, to which is

added other substances, such as shellac as thickeners, or various specific driers to make the cement dry quicker. Where tenacity is specially desirable, other gums, such as mastic and gumlac, are used. So many excellent cements on the market have been tried and tested that the repairman would be unwise attempting to compound his own, especially when these can be purchased as cheap, if not cheaper than the raw materials and made on the premises. The results are more uniform with commercial cements.

Many motorists cannot understand why tire repairing is a somewhat costly process, but it will be evident that great care is necessary at every stage, from preparing the tire and applying the fabric and rubber, to the final curing, and that a certain knowledge is necessary which can only be gained by experience. Then the materials employed are costly, the retreading stock costing about $1.50 a pound for a product of the best quality, while frictioned fabric such as is used in rebuilding, costs about $2.50 the square yard. There is considerable hard work needed and experienced men command good salaries. Then the repairman must stand back of his work and often loses money in endeavoring to please customers by making gratuitous repairs upon tire failures which were due to the motorist's abuse, and not that the work is faulty. The pictures and drawings illustrating the subject are pertinent and will serve to make clear some of the processes and apparatus necessary in tire repairing.

Proportioned Repair Stocks.—In buying repair material, a certain amount is to be invested, and this should be for a properly proportioned stock. To get too much of one thing and not enough of another is vexing and discouraging to the man making a start. It is to overcome this drawback that supply houses offer certain assortments, consisting of the right kinds and the right quality of stock. The assortment mentioned below is merely suggestive. The price quoted on each kind of material aws the market price at the time this book was printed. Prices vary slightly from time to time, and a change, therefore results in the amount of each grade to be shipped. The recommendation is made by the Haywood Tire and Equipment Company of Indianapolis, Ind.

ASSORTMENT A—$100.00

30 lbs. AA tread stock	$0.75	$22.50
20 lbs. AD building fabric	1.00	20.00
10 lbs. AS single friction	.90	9.00
5 lbs. MC cushion stock	1.20	6.00
5 lbs. AB breaker	1.00	5.00
3 lbs. MT tube stock	1.20	3.60
5 gals. SLC cement	1.90	9.50
20 lbs. soap-stone	.05	1.00
1 doz. No. 1 Valve bases		1.50
1 doz. No. 2 Valve bases		1.90
100 Air checks		2.65
100 Valve caps		2.00
1 doz. 777 Valves		3.50
½ doz. 725 Valves		1.85
2—3″ Tube sections	.50	1.00
4—3½″ Tube sections	.60	2.40
5—4″ Tube sections	.75	3.75
2—4½″ Tube sections	.90	1.80
1—5″ Tube section		1.05
		$100.00

A much smaller outfit, suitable for the individual owner or small repair shop follows:

ASSORTMENT E—$5.25

2 lbs. Tube stock	$1.20	$2.40
1 lb. Tread stock	.75	.75
½ lb. Cushion stock	1.20	.60
1 qt. Cement		.70
1 Can soap-stone		.20
1 doz. Air checks		.35
1 doz. Valve caps		.25
		$5.25

How Tires Are Often Abused.—In many instances tires have been received by repairers which show such wear at the sides that the canvas layers are exposed, which is due to three causes, all of which may be directly traced to abuse by the driver of the car to

which they were fitted. This wear may be caused by driving against the curbstones, in car tracks and with the tires deflated. In driving many motorists come up too close to the curb, and the friction at the side of the cover naturally causes it to wear on one side, so that sooner or later the canvas layers are exposed. This usage, if continued, weakens the shoe and a blowout will result. If one drives in car tracks the side of the tread will wear on both sides, as with the usual construction the vogue in many cities there is a space between the rail and the paving in which the tire may be forced, and the friction will cause rapid wearing of the rubber at the side of the tread.

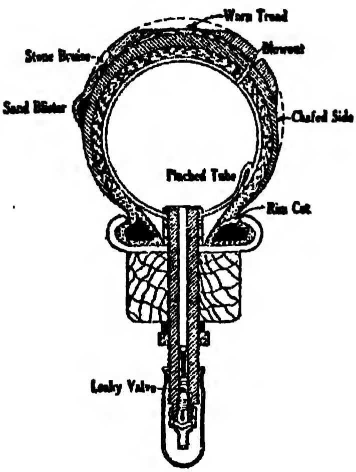


Fig. 433.—Sectional View of Pneumatic Tire, Showing the Defective Conditions Which Demand Attention.

Other reasons for wearing the sides of the cover are traceable to deflated tires. In the case of a shaft driven car the sharp edges of the clincher rim may cut into the casing, this wearing being known as rim cutting, being produced by the concentration of the entire weight of that quarter of the car upon the edges of the rim channel. Wearing by the chain of a side chain driven car is possible, if the tire is not properly inflated. It is evident that the weight will depress the tires and if there is not sufficient air therein it cannot resume the rounded contour under which conditions it clears the chains, and when flattened the sharp edges of the link side retaining rivets will shear off the rubber very quickly.

Another condition in which many motorists are negligent is keeping their tires clean and free from oil and grease, for while

rubber is perfectly waterproof, it is easily affected by oils and some acids, which act as solvents, and if exposed to their action for any length of time it will soften and disintegrate. The first signs of decomposition show only when it is too late, that is, when the tire is beyond repair, and unfortunately there is a tendency to attribute this to an inferior quality of rubber, whereas it is due directly to the solvent action of the oil, and the purer the rubber the more rapid the chemical action. In many types of live rear axles the oil will leak from the housings and get upon the tires. Often the motorist will let his car stand for days at a time in a pool of oil on the floor of the garage or motor house. Oil should be immediately washed off of any of the rubber parts with gasoline or naphtha. The importance of keeping either oil or water away from rubber cannot be too firmly impressed upon the man who wishes to obtain maximum service at minimum expense from his tires.

Why a Tire Depreciates Rapidly.—A most common form of deterioration is ordinary wear of the rubber tread, which depends upon the quality of the rubber used and the number of miles driven; in such a case the fabric, which is really the main support of the tire, is laid bare. This is inevitable owing to the constant friction of the tire against the ground, but many people attribute this wear to inferior quality of rubber, forgetting that even the most resistent of materials will not constantly endure. If one continues to use a tire worn down to the canvas the fabric will wear quickly, and the shoe be weakened so that the walls no longer resist the pressure of the inner tube, which bursts out through the weakened portion. After a tread is worn to the canvas, deterioration will be rapid and the only possible repair is the application of a new rubber tread.

Another cause of tire depreciation is small cuts in the rubber covering which will affect the fabric as well. These are caused by sharp objects, such as broken glass, nails, particles of iron, flints, sharp stones, etc., which stick into the tire. The damage caused may be of two different natures, either the outer cover is cut to a greater or less depth or both the cover and the inner tube are cut through, the tire being temporarily rendered useless in the latter

instance, which is the "puncture" that is the dread of motorists.

Assuming a sharp object has cut a gash into the cover, but has not reached the inner tube. In such an event, especially if the layers of fabric have not been damaged the driver can go on for the moment without repair. It is different when one or more of the layers of canvas have been cut into. In that case water, sand, grit, etc., work into the cut and cause the tire to blister while water will produce rotting of the fabric, either of which conditions if not given immediate attention becomes fatal to the outer cover. Sand will work between the layers of rubber or fabric and produce lumps known as sand blisters, which often puzzle the driver and give rise to all manner of surmises as to their cause.

Water Rots Fabric.—The average motorist does not usually consider water an enemy to tires, and it is not so long as it stays outside. Moisture has very little effect upon the rubber, but damages canvas to a great extent. Cotton fabrics and in fact all vegetable fibres which have as a general basis cellulose, such as flax, jute and hemp, can offer resistance remarkably well to atmospheric influences such as oxygen, heat and damp, which affect so many organic substances. For instance, it is said that a piece of cotton exposed for a month in the air, the sun and the rain, does not lose more than two per cent. of its original strength and other pieces wetted and ironed dry 20 times in succession only lost three per cent. If left under water for six months, the cotton fabric used does not lose much of the dynamic force although the water itself may be covered on the surface with mold. But if cotton is left in a damp place, on the damp floor of a cellar, for instance, it will get spotted in a very short time, on account of the mold, microscopic fungi, mildew, and other minute agents of destruction. This effect is well known to motorists as wall papers, which are often made of cellulose fibres, will fall to pieces and crumble when on the walls of damp rooms or closets. It is this same result which often causes bursting of tires apparently in good condition, the first time used after standing all winter, because the cotton fabric is rotten. This has been proven by testing the canvas, the reduction of resistance being 50 to 75 per cent. of its original value because of the weakening of the fibres due to the chemical action. The

importance of keeping water from the interior of a tire should be apparent, and this can be best done by keeping the tires properly inflated, so that the beads will hug the rim, forming a water-tight joint, seeing that all tire and valve lugs have suitable washers under the nuts, that the valve is provided with suitable packing washers, and lastly that all cuts of any size which penetrate to the fabric are filled with new rubber by vulcanizing.

Describing Repair Processes.—In describing methods of restoration reference will be made to the processes for retreading, rebuilding, making sectional repairs, and simple inner tube work. Retreading is necessary when the outer tread has so worn through normal use that the canvas shows in spots, and it can only be done with profit on casings that are strong, in which the fabric carcass or body has not been weakened by blowouts or rim-cutting. Rebuilding a tire is replacing weakened or destroyed fabric by new material and making a new tread. It is a more expensive operation and is seldom profitable. In case of a large puncture or blowout in a casing (providing the rest of the shoe is in good condition), it is only necessary to build the tire over at the weakened spot. This is known as sectional work and is perhaps the most common method of repairing known. Tube work is simple and the method depends upon the size of the hole to be sealed. The necessary ma-

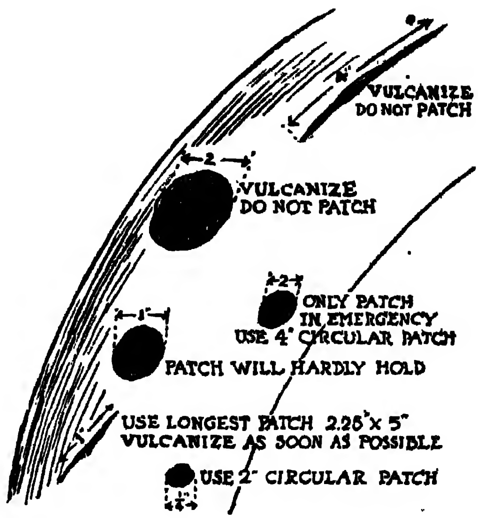


Fig. 434.—View of Inner Tube, Showing the Various Sized Holes and Sizes of Patch to Use in Making Repairs, also Defects that Cannot be Patched but Must be Vulcanized.

terial and stock may be purchased but experience can only be obtained by constant endeavor to improve, and knowledge is the most important asset of the successful tire repairman.

Tire Tube Repairs.—Tire tube work includes repairing punctures, blowouts, cuts due to pinching in application, or by poorly fitting security bolts, and inserting new valves. After locating the opening, the rubber is slightly roughened with a piece of emery cloth for an inch and a half on all sides of the hole, the surface is cleaned thoroughly with benzine, cemented, filled in with unvulcanized stock or a patch and cured on a flat plate. Cuts are treated as previously described to insure absolute cleanliness, the edges are cemented and brought together with unvulcanized stock to form a union, and cured, as in the case of a simple puncture. Blowouts or large punctures require different treatment after the rubber has been thoroughly cleaned, as the size of the hole seriously weakens the tube. The area around the opening is well cemented, both inside and out, inside patching material is placed inside the tube, the space between the edges of the hole filled in with unvulcanized material, stitched carefully, placed on a flat plate and cured. The length of time in heat is governed by the quantity of material and quality of the tube to be cured. This will vary from 10 to 25 minutes at a steam pressure of from 35 to 50 pounds. In applying valves a piece of rubber known as the valve pad is vulcanized to the inside of the tire instead of the inside patching, this serving as a reinforcement and forming a firm base for attachment of the valve.

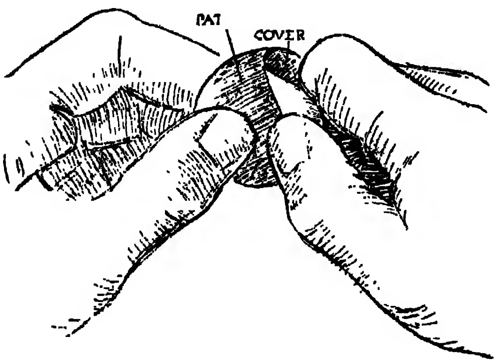


Fig. 435.—How to Remove the Cloth Cover to Expose Cemented Surface of Prepared Patch for Inner Tube Repairs.

Replacing Valve Stems.—There are a number of occasions where the valve stem of an inner tube becomes defective due to either the stripping of the external threads so that the pump connection cannot be securely screwed on, stripping of the valve thread inside which prevents the removal of the check valve and bending of the stems due to careless handling in removing it from the rim. Another common failure is shearing off of the projections on the valve inside by which it is intended to be unscrewed, which means that the valve cannot be taken out when it becomes leaky. Of course, any one of these defects temporarily destroys the usefulness of the inner tube. If that member is comparatively new or still serviceable, a new valve stem may be easily inserted. The repairman who does tire work will find it advantageous to cut out all the valve stems from old inner tubes which may be in his possession, and even when an inner tube is entirely worn out the valve stems may be in good enough condition to warrant saving them until an opportunity presents itself for using them. A defective valve stem may be taken out of the inner tube without injuring it by releasing the clamping nut and removing it and the casing spreader, then removing the corrugated washer which holds the tube against the button-shaped inner end of the stem. The portion of the tube adjacent to the stem can be carefully loosened and the button end separated from the rubber by forcing the stem into the tube. Some gasoline or naphtha may facilitate loosening of

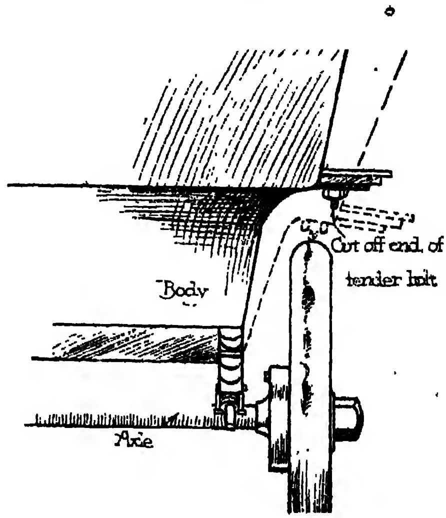


Fig. 436.—How Tire Tread is Sometimes Injured by Projecting Bolts of Fender Iron if Springs Deflect Excessively.

the valve base if cement has been applied. If a pair of special tire pliers is at hand their point can be insertcd into the hole and the hole can be stretched until it is sufficiently large to pass the button end of the stem through. The button end of the new valve stem can be placed in a hole when this is elongated and some cement may be applied to the contracting surface of the stem end as a lubricant to

Fig. 437.—Showing Method of Locating Punctures in Inner Tube by Immersing it in a Tank of Water, the Escaping Air Indicating the Presence of the Leak by Bubbles.

facilitate entrance into the interior of the tube. The pliers are then removed and the tube allowed to constrict around the valve stem. Some cement is placed on the corrugated face of the clamping washer, then the spreader is put on over the stem and the clamp nut screwed down and tightened. By partially inflating the tube

Fig. 438.—Showing Method of Cleaning Area Around the Puncture with Emery Cloth or Sandpaper Before Applying Cement to Tube.

and submerging the stem portion in water one can easily determine if a satisfactory repair has been effected. Care should be taken in replacing the clamp plate or spreader so that its greatest length is lengthwise of the tire. The function of this is to protect the tube at the point at which the valve is attached. It also aids in holding the casing in place on the rim to some extent.

Simple Casing Repairs.—In event of a damaged shoe, the extent of damage and whether the hole is through the cover, or only through the rubber is ascertained. If only the tread is affected it will not be necessary to remove any of the canvas layers, but the

Fig. 439.—Showing Use of Wire Bristle Buffing Wheel Attached to Spindle of Small Portable Drilling Machine for Cleaning Area Surrounding Puncture on Inner Tube.

rubber must be cut away for one or two inches around the broken surface. The edges cut bevel, then roughened with a rasp or emery wheel; then apply two or three coats of vulcanizing cement, allowing each to dry thoroughly and build up with cover stock to surface contour, dust talc over the mold, clamp tightly, and vulcanize.

Repairs May Be Made From Inside.—If the hole is through the tread and body, and it is not too large, such as is caused by a simple puncture, a good deal of work can be done from the inside of the tire and very little rubber need be removed from the tread.

In a simple puncture no rubber need be removed. For a small blowout it is only necessary to fill in that part of the tread or cover that was blown away. In making repairs from inside it is necessary to turn the casing inside out, and remove two or three plies of fabric inside, "stepping down" each ply, as shown at Fig. 443, the last ply to be within two inches of either side of the edges of the hole. Clean thoroughly and apply at least three coats of vul-

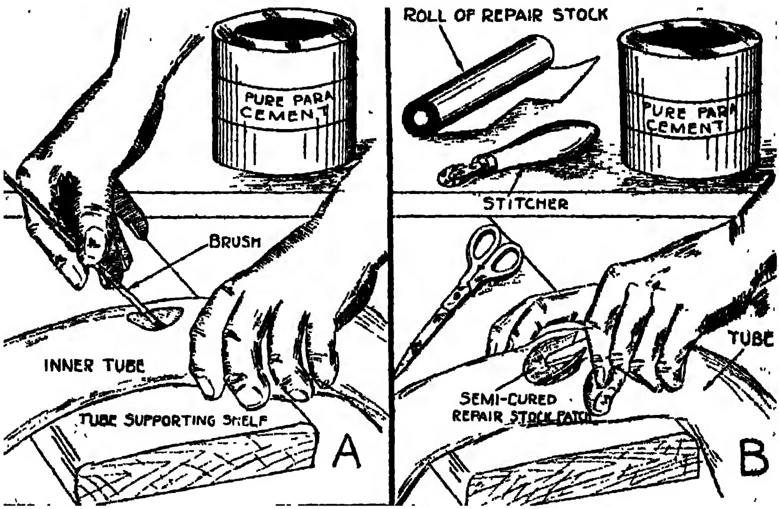


Fig. 440.—Preparing Inner Tube for Vulcanizing Patch. A—Coating Inner Wall of Tube with Rubber Cement. B—Inserting Semi-Cured Repair Stock Patch.

canizing cement, allowing each coat to dry thoroughly before applying the next. This will require about an hour for two first coats and three hours for the last. Cover the inside of the fabric with 20-gauge unvulcanized stock, turn the tire back as it should be and replace the fabric removed with new stock by a "stepping-up" process, applying one or two extra layers of plies in the inside extending for several inches beyond the other material, this to make the repair as strong as any other part of the tire. Fill in the outside surface with raw stock, place the tire in a sectional mold,

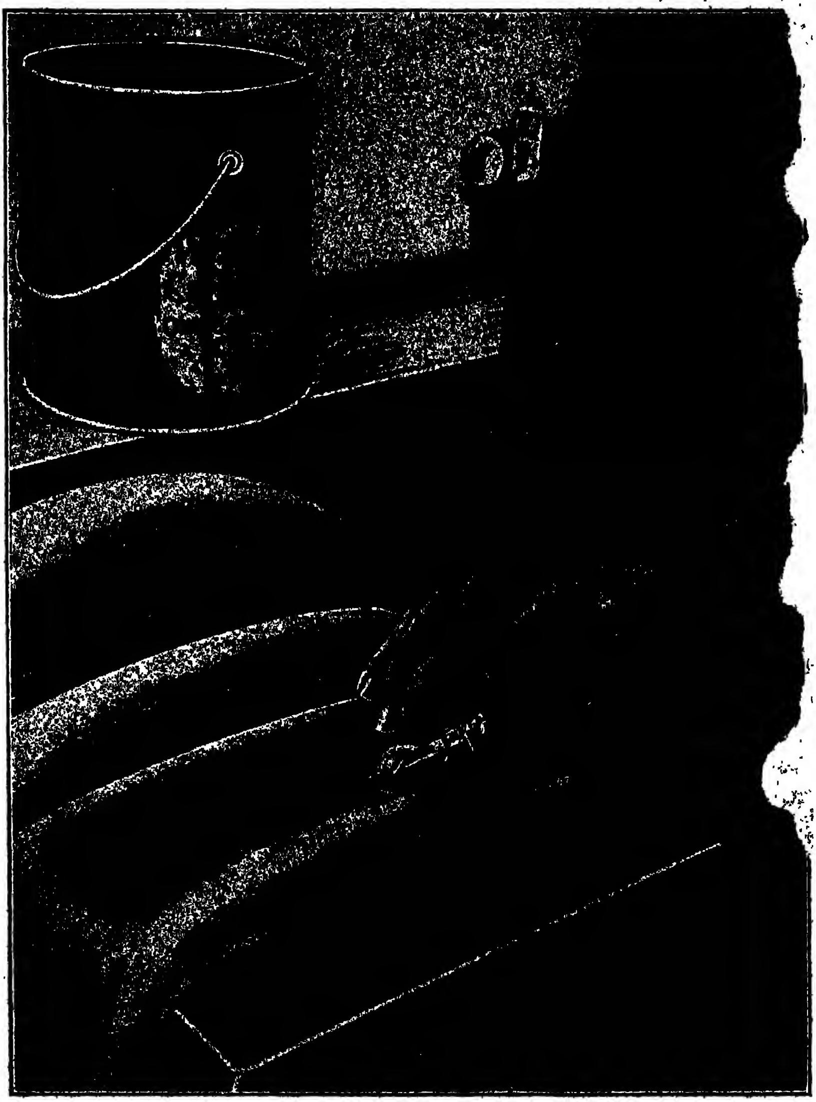


Fig. 441.—Showing Use of Stitcher in Rolling Patching Rubber to Make Firm Contact with Inner Tube.

ısting both mold and tire over with talc powder, and after placıng an air bag or substitute inside the shoe inflated from 40 to 60 pounds pressure the curing follows. It is recommended that the tire be wrapped at each end of the mold for about six inches with a bandage, this to hold the case together and prevent distortion or bulging out of the air bag. The curing continues from 45 minutes o one hour at from 50 to 55 pounds, according to the size of the tire.

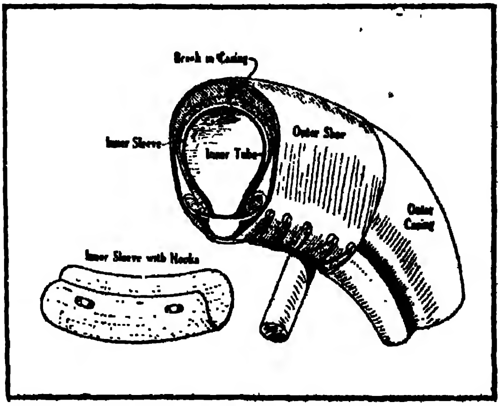


Fig. 442.—Showing Method of Using Inner Sleeve and Outer Shoe in Making Temporary Repair of Blowout in Casing.

Another method of making this repair, and followed if the blowout is at all serious, 's to remove the old tread for four or five inches on either side of the opening. The tire ; then restored with new stock, after the inside has been treated as previously described and weakened or broken fabric replaced by a stepped series of lay- of fresh material. A point that must be observed is to remove a ficient quantity of the tire stock to insure that fabric enough will be used on the shortest step, which is that next to the cut, so that it will bridge over the hole and leave a substantial margin of canvas at either side. As it must be evident that there is considerable strain against the patched portion of the tire, the greater the area over which the stress is distributed the stronger the repair. Each ply of fabric or rubber should be well rolled with the stitcher so that every part of it will adhere, and if air is left between the layers, forming bubbles, these will cause loosening of the covering when the tire is in service. Air pockets should be struck open with the point of an awl moistened with water before making a hole, as the edges will close together more readily if this precaution is taken.

Retreading and Rebuilding Tires.—If a tire has become worn

through normal wear, it is possible to put a new tread on the old fabric body and add considerable to the life of the tire. To re-tread a tire the first operation is to remove all the old tread down to the fabric. This is done by cutting straight across and through to the first breaker strip, and pull this away from the tire proper, using gasoline or benzine to assist in loosening it from the padding. The remaining rubber is cut away with a sharp knife moistened in water, and then all traces of the old tread are removed with the wire brush, emery wheel or rasp. If the fabric has been damaged, as sometimes results when the tire is run with the tread worn so that the plies are exposed, each injured layer should be cut off. After buffing, the outside of the shoe is thoroughly washed with gasoline, and when this has evaporated three coats of vulcanizing cement are applied, allowing the last one to dry about three hours. A coat of 20-gauge cover stock is applied as padding, and over this is placed a breaker strip, then another layer of cover stock, also used as padding, this covering the breaker strip only. Over this padding is applied a sheet of 60-gauge retreading stock, allowing it to extend one inch each side of the breaker strip; apply a second layer of the same stock about one inch narrower, and over this is laid another strip of retreading stock of the same gauge as the others which extends to the point formerly the edge of the old

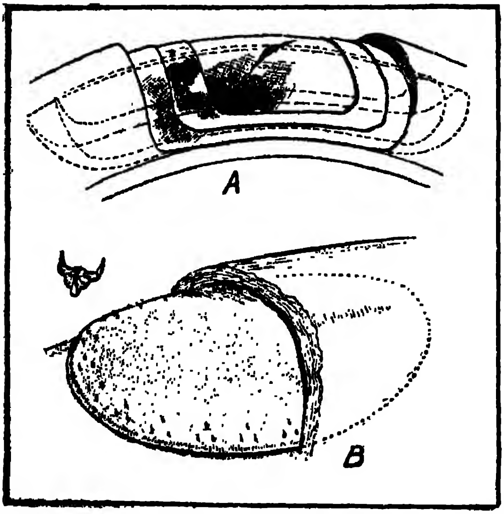


Fig. 443.—At A, Method of Stepping Down Fabric and Tread of Outer Casing when Repairing Blowout by Sectional Vulcanizing Process. At B, an Inside Patch that is Held in Place by Mechanical Means Instead of Cement is Shown.

tread. Each ply is rolled thoroughly and stitched and all air is released from air blisters. The shoe is now ready for curing.

Rebuilding is very similar to retreading except that new fabric is used to replace any that is not up to the standard in the body or carcass of the shoe. The tread is removed as in retreading, and the first ply of fabric is cut through all the way around on the

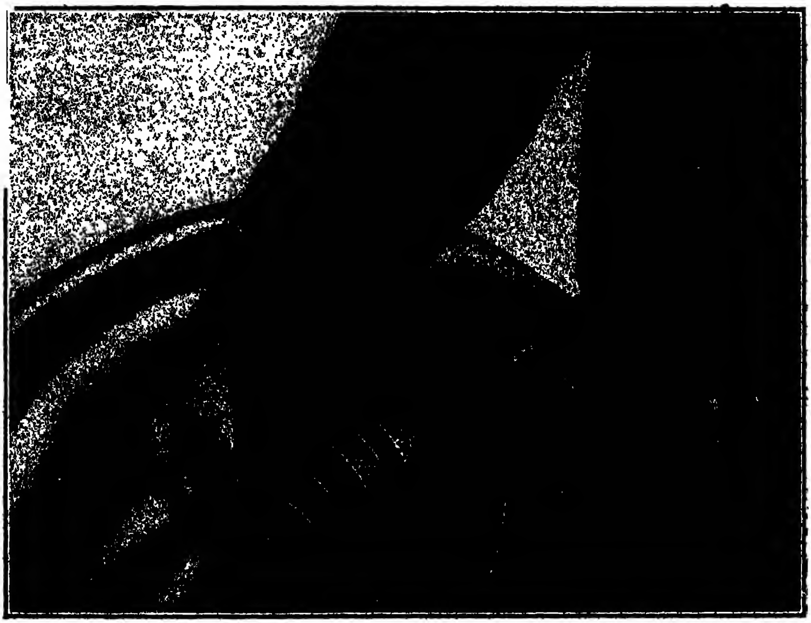


Fig. 444.—Showing Method of Stripping Off Worn Fabric from Section of Old Casing to Make a Very Satisfactory Inside Patch for Blown-Out Casings.

center of the tire. After cutting, this ply is turned back all the way around to within one-half to one inch of the bead. The weakened plies are removed, never more than three, as more than this makes the cost of this mode of restoration prohibitive. Assuming that two plies are removed, cut out the first all the way around within one-half inch where the first ply is turned back. Remove the next ply within one-half inch of the second and clean the tire thoroughly, applying three coats of cement. It is imperative that

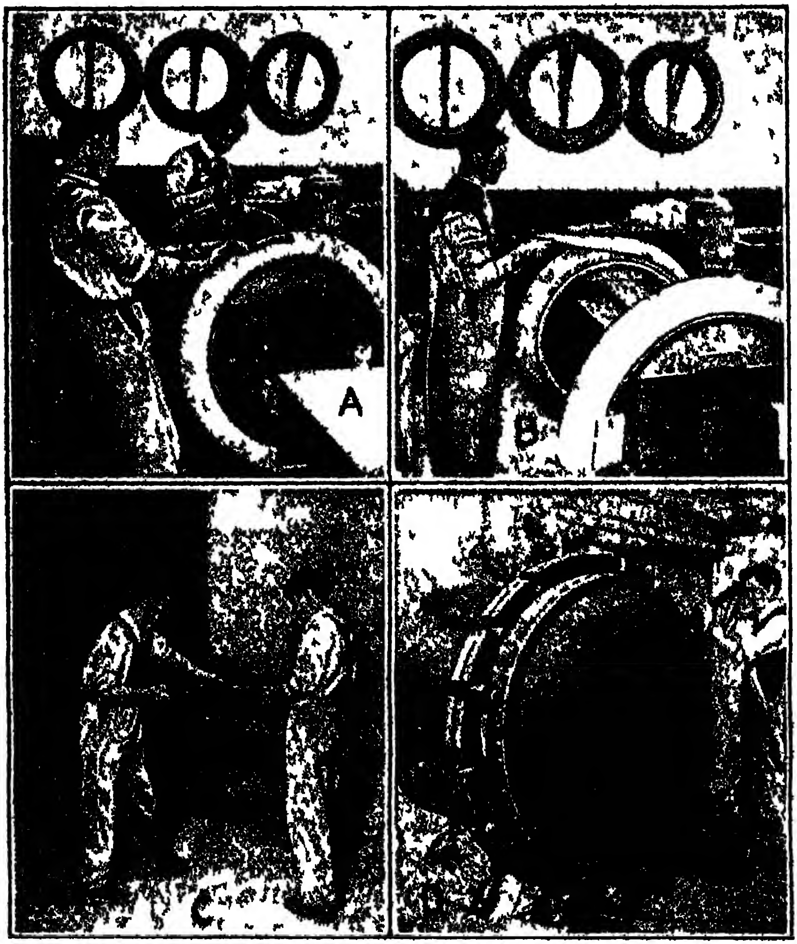


Fig. 445.—Depicting Various Steps in Retreading Casing A—Stripping Off Defective Tread Rubber B—Applying New Cover Stock C—Wrapping the Casing Firmly with Strips of Cloth D—Bolting on Cover of Steam Oven Retreading Type Vulcanizer.

the cement coatings dry thoroughly. Twenty-gauge cover stock is applied over the cement and rolled thoroughly, and rebuilding c, cut on the bias, is used to replace the plies previously removed. The part of the tire that is turned back is rolled into proper position, the union at the edges being made with unvulcanized pure gum stock, and the remainder of the process is the same as in retreading.

Many rim cut clincher tires are brought in, the damage resulting from use without sufficient internal air pressure, and in some instances it is possible to make a very satisfactory repair upon these. The rubber is removed from the cover on the side for about an inch and a half or two inches above the bead and then a ply of fabric is removed about one-half inch from the toe of the bead. If more than one ply is cut the next ply should be cut away one inch more than the first. Clean thoroughly and cement. Twenty-gauge cover stock is applied, the rebuilding fabric to take the place of each layer removed, the last ply to be cut wide enough to turn inside the casing from two to three inches. An amount of unvulcanized stock about equal to that removed from the cover is then applied and the tire is ready for curing.

In tire retreading or rebuilding, certain essential factors, if observed, will insure success. The parts must be thoroughly cleaned before application of cement, and all coats should be allowed to dry at least the time specified by the makers. Every layer of material applied, whether fabric or rubber stock, must be firmly rolled to insure proper adhesion, and it is imperative that air bubbles be punctured and the air released. The best cements and stocks to use are dictated by experience, and the gauges of the stock applied will vary with the individual preference of the repairman, though these should be chosen with reference to the material in the tire that is being restored.

To cure a rebuilt or retreaded cover in the large pot heater it is necessary to have air bags of the proper size for each tire, as those that are too large may become pinched, while those too small will not properly fill the interior of the casing. After an air bag (which is in reality either a portion or entire specially made tire tube) is placed in the case, the tire is assembled on the rim and

wrapped spirally with a bandage of sheeting or light duck about three inches wide. Next the air bag is inflated to 40 or 50 pounds pressure, and the tire is placed in the heater and cured, the period of curing depending upon the size of the repair, varying from 30 minutes to one hour and at pressures of steam varying from 40 to

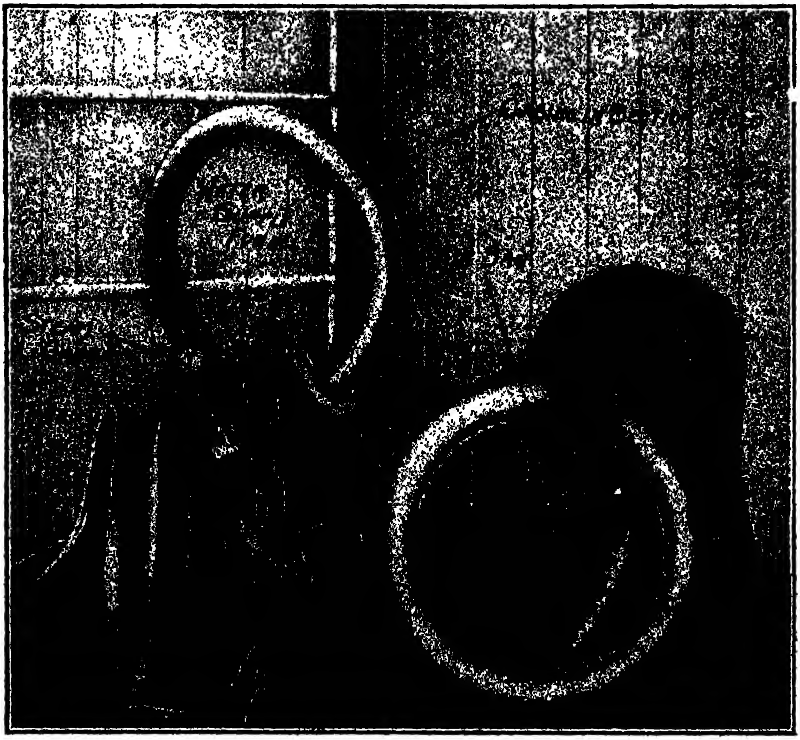


Fig. 446.—Corner of Typical Repair Shop, Showing Practical Application of Vulcanizer on Both Tube and Casing Work. Notice Insertion of Air Bag in Casing Before Putting Same in Sectional Mold.

50 pounds. In curing special care must be taken and in this process many inexperienced operators make error. If a casing is cured too long the rubber will be too hard and will lose resiliency or life; while if the curing process is hastened and the tire is not properly heated, the rubber will be soft and repair unsatisfactory. After

removing the tires from the heater they are allowed to cool about 30 minutes, then unwrapped and hung up for a day or two to set. Steam at a pressure of 40 pounds has a temperature of about 250 degrees Fahrenheit and is the heat commonly used in curing rubber.

Dry Cure Methods.—There are two systems of vulcanizing when making sectional repairs or retreading, that best adapted for general use being the dry cure system in which the desired pressure for vulcanization is secured with pads instead of with an air bag and where the tire is cured by the application of heated elements rather than wrapping it and placing it in a steam oven. A number of molds used in the dry cure system and sold for use with the Haywood vulcanizer have been previously described and illustrated in connection with that outfit at Fig. 430. Additional appliances are shown at Fig. 448. That at A is known as an inside patch or relining mold and may be used in relining, patching or for drying out the interior of a casing before a reenforcement is started. On blowout work, especially of the larger and more difficult class, it is often necessary to apply two or three layers on the inside of a tire, and although considerable heat is conducted from the outside mold it is well to give the repair a twenty minute cure on the inside which is best accomplished with the form of mold shown at A.

Solid pads and clamps are used in connection with the various types of Haywood molds for obtaining pressure on the curing stock. These pads conform to the curvature of the mold on which they are used. There are a number of advantages given for the pad and clamp system, over the air bag system. It is said that the properly built pads last indefinitely, whereas the air bags have a definite life and are subject to the uncertainty incidental to the use of pneumatic appliances. With a solid pad on one side of a repair and a substantial accurately machined mold on the other and with three to five heavy iron clamps drawing the two together it is possible to exert more pressure on the curing stock than by any other system and pressure is considered an essential to good work. The pad and clamp system is simple and easy to operate and there is nothing in its operation that calls for skilled labor. It not only produces considerable pressure on a repair but also localizes the heat to the portion being repaired.

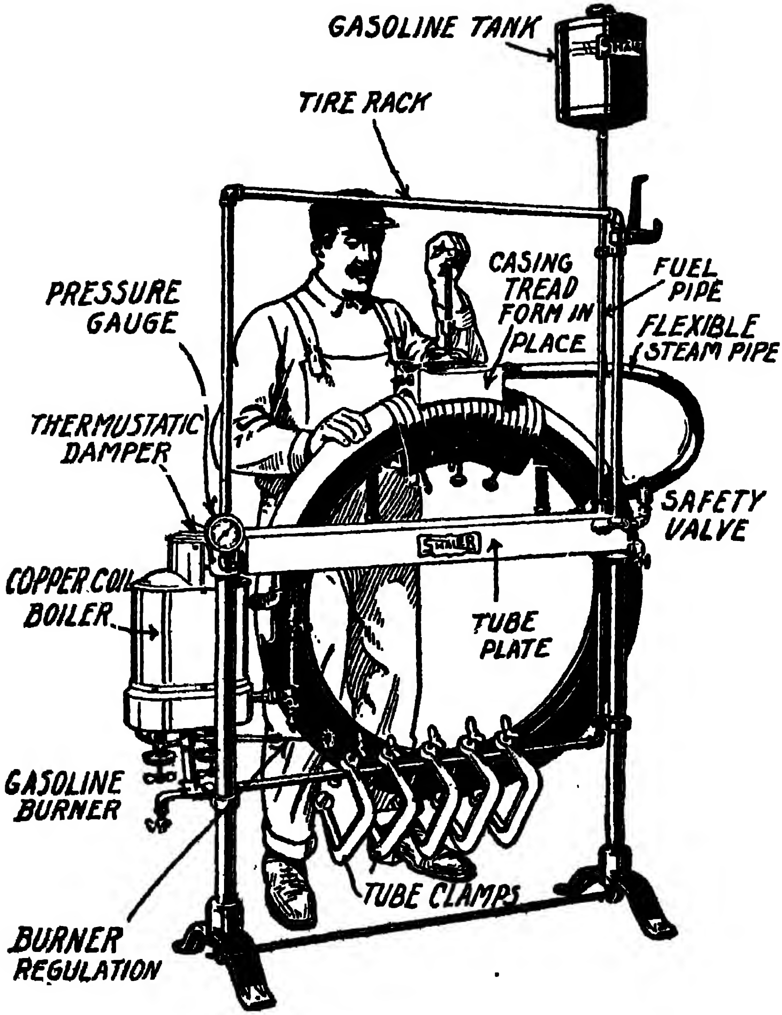


Fig. 447.—Use of the Shaler Automatic Vulcanizer in Making Sectional Repair on Outer Casings.

The method of using the pressure pad in making a repair on a defective tire bead is shown at Fig. 448, B. The side wall and bead mold is shown at C, while the appearance of a repaired portion of a casing having a long rim cut and blown side wall is shown at D. Retreading may be also easily accomplished by the dry cure method. The appearance of a tire needing retreading is clearly shown at Fig. 449, A. This is only practical if the layers of fabric are in good condition. The old tread is stripped off as previously de-

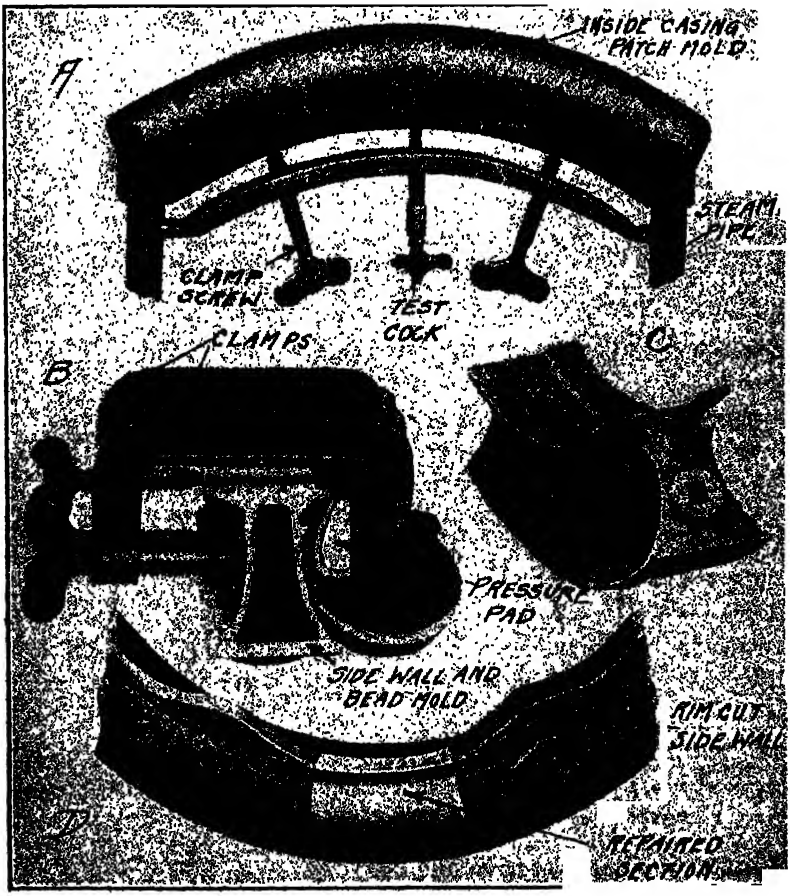


Fig. 448.—Molds for Use with Dry Cure Process of Vulcanizing.

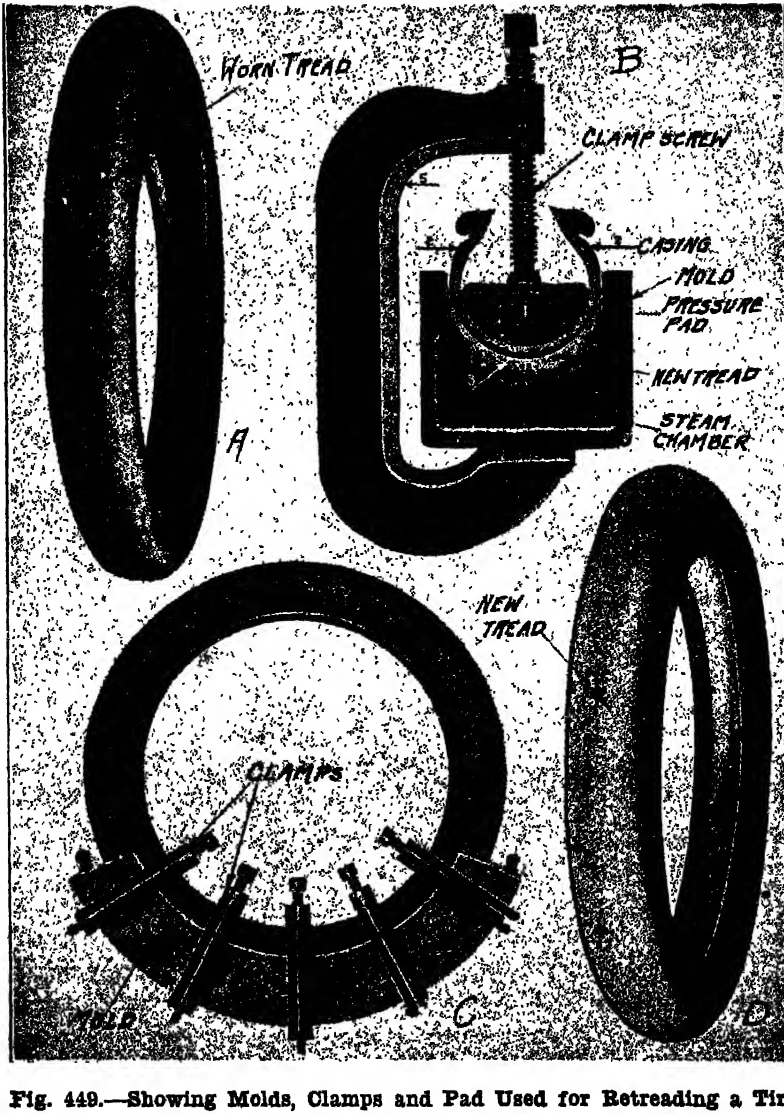


Fig. 449.—Showing Molds, Clamps and Pad Used for Retreading a Tire by the Dry Cure Process.

scribed and the new tread cemented on and vulcanized by the use of a retreading mold which is shown at Fig. 449, C. The retreading molds are 26 to 28 inches in length and heat approximately one-third of the circumference of the tire at one time. The molds are hollow, allowing steam circulation from one end to the opposite and have an opening at the lowest point to exhaust the products of condensation. The sectional view of the mold with the clamp and casing in place shown at Fig. 449, B, shows the construction of the mold and the method of applying the new tread very clearly. The appearance of a retreaded tire after the new tread has been cured on is clearly shown at D. Sectional molds, which are the forms previously described are simply short retreading vulcanizers. They are used for curing the tread portions where the injured section is not long enough to call for the use of the retreading mold shown at C. Sectional molds are the forms to use for surface cuts, sand-blisters, stone bruises, short patches of loose tread and other defects confined to a specific area of the tire.

Reconstructed Tires.—A new method of tire salvage has been recently devised by which two old casings may be combined to form a new casing, this being especially desirable when one of the casings has a good bead but a poor tread while the other one may have a good tread but be defective at the bead. This process is called reconstruction to distinguish it from retreading as it consists of stitching the two tires together in such a way that they cannot separate, using the one with the best bead for the inside member. The entire feature of the repair lies in the stitching process, and as this is not an easy one a number of firms are in existence which have special machinery for doing this work. Sometimes the process includes adding a special layer of calendered fabric to the surface of the inner tire. Another process includes the addition outside of the second tire of a non-skid surface composed of steel studs fastened into a special fabric, this being firmly cemented to the casing.

The appearance of reconstructed tires is shown at Fig. 450. In one process the procedure is substantially as follows: the cover is first subjected to examination and if found satisfactory for repairing is transferred to the stripping machine which strips the whole

of the remains of the old rubber tread from the canvas base. Any cuts, bruises or bursts are then cut clean and built up with fresh fabric and rubber and the cover is then treated to a process that forces a rubber compound under heavy pressure into the spaces between the layers of canvas where movement between them has produced separation. To the whole of the inside of the cover one or two layers of specially prepared canvas are applied, the cover

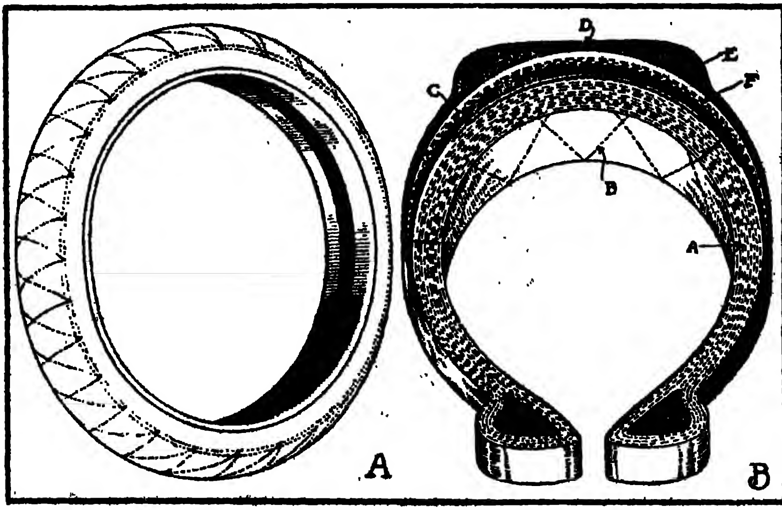


Fig. 450.—Method of Combining Worn Tires and New Material to Produce a Reconstructed Casing Capable of Giving Considerable Additional Service.

being put into a special sewing machine which covers it with a network of stitching which runs through the entire carcass, this reducing the internal movement of the layers relative to each other to a minimum. A final lining of friction canvas is attached to the inside over the stitching. The stitching and treatment up to this point form the basis of the patent which protects the manufacturers repairing by this process. The illustration at A indicates the stitching of the inner cover before the outer cover is applied. The view at B shows the completed unit with the other tread in place and fastened to the inner cover. In this view A indicates the old cover with its tread removed, B, the cross sewing, C, the

joining rubber, D, the new tread, E, dark rubber forming the new tread, F, light rubber and canvas forming the base of the new tread. After the cover has been stitched as shown at Fig. 450, A, the next stage is to treat it to a generous layer of rubber compound on the outer side and the prepared jointless tread is carefully fixed in place. The cover is then filled with molds which are hammered into place to stretch the cover base into its original shape and approximating as near as possible the shape it assumes under working inflation pressure. The next process is the wrapping and binding of the cover. This is then followed by treatment in a vulcanizer from whence it emerges with the tread attached to the original canvas base by a thick layer of resilient black rubber. It is said that the life of a reconstructed tire is often equal to that of a new one whereas the cost of reconstruction is but 50% of that of new tires in most cases.

Repairing Punctures with Mechanical Plugs.—Repairmen who have had experience in bicycle work are thoroughly familiar with the advantages as well as the limitations of the screw down plug which has been widely sold for repairing single tube bicycle tires. A modification of this form of plug has been introduced for use on inner tubes and has the advantage of being very easily handled though its use is limited to the repair of small punctures. The plug itself consists of two threaded discs of metal which are firmly vulcanized in a surrounding mushroom shaped mass of rubber. The lower one of these has a stem attached to it on which the upper head is threaded. The plug is clearly shown at Fig. 451. For motorist's use these are sold as a kit with a set of special pliers to facilitate manipulation. The first operation after the puncture is located is to use the conical punch end or cutter as indicated at C, which makes a smooth round hole that is not apt to tear. The next operation is to stretch the hole as shown at D in order to permit the insertion of the lower portion of the plug. After this is in place the upper part is kept from turning as shown at Fig. 451, E, by pressure of a finger, while the lower portion is brought tightly to bear against the inner tube which is sandwiched between the two parts of the plug by turning the bent part of the stem which acts as a lever and makes possible the secure retention of the inner tube

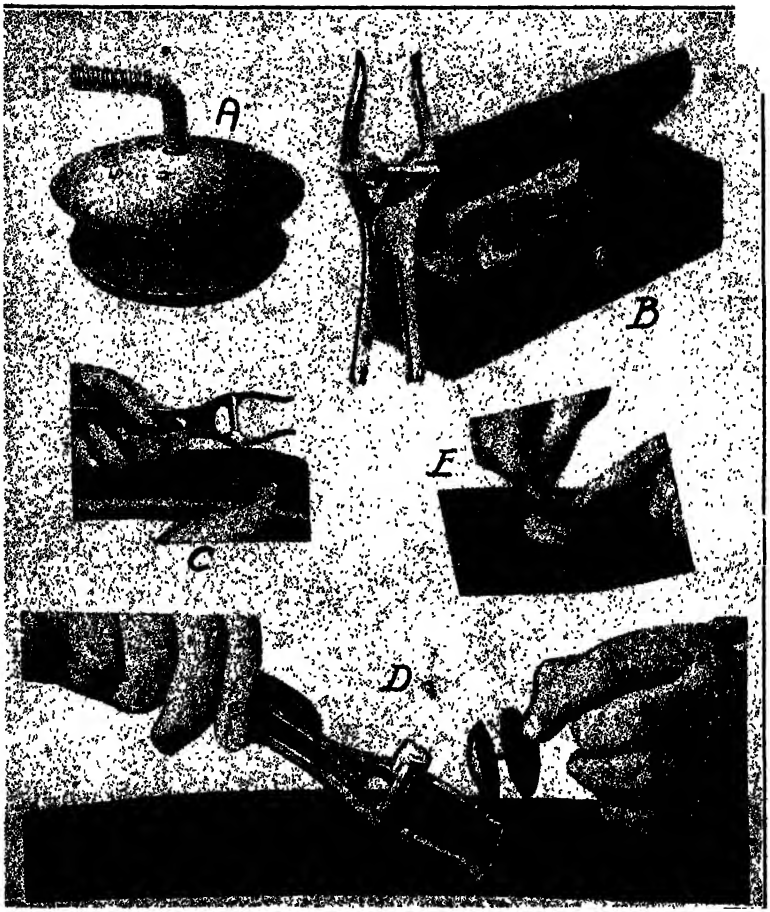


Fig. 451.—How Inner Tube Punctures May be Repaired with Sampson Mechanical Repair Plug.

between the upper and lower portions of the plug. After these parts have been tightly screwed together, the projecting end of the threaded stem is broken off or cut with the pliers and if any projects it is smoothed down with a file. In order to prevent the plug cutting through as would be the case with metal plugs the edges of the rubber pieces are very flexible and soft which, of course, prevents them cutting into the inner tube.

AIR PRESSURE AND CARRYING CAPACITY PER WHEEL OF STANDARD SIZED PNEUMATIC TIRES

For weights in excess of 1,000 pounds per wheel, 5-inch tires or larger are recommended.

Size, Inches	SINGLE		DUAL
	Extreme Load per Wheel, Pounds	Air Pressure Recommended, Pounds	Extreme Weight per Wheel, Pounds
28 to 36x2½	225	40	
28 to 36x3	350	50	
28x3½	400	60	
30x3½	450	60	
32x3½	550	60	
34 and 36x3½	600	60	
30x4	550	75	
32x4	650	75	
34x4	700	75	
36x4	750	75	1200
32x4½	700	85	
34x4½	900	85	
36x4½	1000	85	1350
36x5	1250	90	1500
38x5½	1350	90	2000
40x6	1500	90	

INCREASE IN AIR PRESSURES CAUSED BY DRIVING

The figures given by tire manufacturers as the most suitable for initial inflation generally take into account the increase in temperature and pressure created by prolonged running. It, however, is useful to know what this increase is. The figures in the following table are given by a French authority and are averages computed on tires from 3 to 4½ inches diameter under usual touring car weight and speed conditions. For larger tires the increase is greater on account of the greater rigidity of the cover walls, resulting in greater internal strains in the fabric at the points of bending.

Initial Pressure in Tire, Cold. Pounds per Square Inch	Working Pressure in Tire, Warm. Pounds per Square Inch	Increase Resulting from Work. Pounds per Square Inch
71.116	88.183	17.067
85.339	105.750	20.411
99.562	123.546	23.984
113.785	141.920	28.135

MAXIMUM CARRYING CAPACITIES OF SOLID TIRES

SINGLE		TWIN	
Size, Inches	Extreme Load per Wheel, Pounds	Size, Inches	Extreme Load per Wheel, Pounds
2	500		
2½	750	2½	1900
3	950	3	2500
3½	1375	3½	3500
4	1750	4	5000
5	2000	5	6000
6	3000	6	8000
7	4000		

METRIC TIRES AND THEIR AMERICAN EQUIVALENTS

Metric Sizes	Approximate Size in Inches	Metric Sizes	Approximate Size in Inches
650 x 65	26 x 2 ½	870 x 90	34 x 3 ½
700 x 65	28 x 2 ½	910 x 90	36 x 3 ½
750 x 65	30 x 2 ½	960 x 90	38 x 3 ½
800 x 65	32 x 2 ½	1010 x 90	40 x 3 ½
830 x 65	33 x 2 ½	815 x 105	32 x 4
860 x 65	34 x 2 ½	875 x 105	34 x 4
700 x 85	28 x 3 ¼	915 x 105	36 x 4
750 x 85	30 x 3 ¼	820 x 120	32 x 4 ½–5
800 x 85	32 x 3 ¼	850 x 120	33 x 4 ½–5
860 x 85	34 x 3 ¼	880 x 120	34 x 4 ½–5
760 x 90	30 x 3 ½	920 x 120	36 x 4 ½–5
810 x 90	32 x 3 ½	1020 x 120	40 x 4 ½–5
840 x 90	32 x 3 ½	1080 x 120	42 x 4 ½–5

CHAPTER XI

MISCELLANEOUS REPAIR PROCESSES

Oxy-acetylene or Autogenous Welding—Torches for Welding—Sources of Gas—Cost of Autogenous Welding—Instructions for Operating—Welding Cast Iron—Method of Preheating—Welding Aluminum—Welding Malleable Iron—Welding Brass and Bronze—General Hints—Treatment of Steel, Annealing—Box Annealing—Hardening—Pack Hardening—Tempering—Case Hardening—Distinguishing Steel from Iron—Hardening Steel Tools—Temperatures for Tempering—Molten Metals to Produce Desired Heat—Working Iron and Steel—Annealing Chilled Cast Iron—Bending Pipe and Tubing—Filling the Tubing—Pipe Bending Fixture—Straightening Out Bent Fenders—Removing Dents in Tanks—Soldering and Brazing Processes—Fluxes for Soldering—Solders and Spelter for Different Purposes—Lead Burning—Soldering Aluminum—How to Braze Iron and Steel—Testing Lubricating Oils—Evils of Exhausting in Closed Shop—Instructions for Repairing Storage Battery—Care of Grinding Wheels—Speeds for Grinding Wheels—Grading of Grinding Wheels.

MANY men are engaged in the automobile repair business who have been specialists in some particular branch of mechanical work before becoming interested in the automobile. Wood workers, blacksmiths and carriage smiths are especially noted owing to the decrease in carriage and wagon work and increase in automobile repairing. The review of various mechanical processes which follows cannot fail to be of value to all those not thoroughly familiar with all branches of mechanical work. Even the automobile mechanic will find the material useful for review.

Autogenous Welding.—Autogenous welding is the process of uniting metal surfaces by heat without the aid of solder or compression. High temperature, full control and easy application of the heat are necessary requisities. The most satisfactory method is termed the oxy-acetylene process, the flame having a temperature

of about 6300 degrees Fahrenheit. By this process iron, steel, cast iron, aluminum, brass, copper, platinum and other metals may be so perfectly united as to defy detection when the joint is smoothed. Its uses include the following: Reclaiming light and heavy castings coming from the sand with blow holes, sand holes, cold shuts and lugs off; reclaiming light or heavy cracked or broken aluminum; adding metal to parts subjected to friction; repairing large or small frame members in place, welding in new parts or filling in cracks; welding split piping or flanges on pipes; reclaiming imperfect steel castings; extending short shafting, adding small metal parts broken off or missing and renewing teeth broken from gear wheels. This process is of inestimable benefit to the automobile repairman and every first class mechanic should have experience in handling the welding torch. Its uses in the repair shop are legion.

The operation of cutting steel or iron is by heating the metal at the first point of contact to the red with the ordinary welding flame. This flame is then continued with a jet of pure oxygen turned on, which unites with the carbon of the metal and disintegrates it with surprising rapidity. The cut is narrow and smooth, with no material damage by oxidation. It may be made in any shape, and the process will be found especially valuable in making many kinds of dies and in fitting steel plates. Steel beams in structural work, steel arches, steel boilers, steel piling, shaped deck plates for steamships and the hardest steel vaults may be cut with ease. The secret of the process lies in the high temperature of the flame, which increases the temperature of the metal so rapidly that very little heat is diffused into the body of the part, most of it therefore being available for fusion. The number of heat units actually absorbed by the metal is a very small fraction of that required to bring the same part to a brazing heat with the ordinary gas or oil blowpipe, and very little if any warping takes place.

One of the first points to be understood when considering the use of autogenous welding is that the heat actually has to come in contact with every particle of metal welded. It is impossible to weld by this method where this cannot be done. If a small boss is required on a given casting, it is useless to cut out a disc of metal the same size of the boss with the idea of welding it on. The cor-

rect way would be to add metal drop by drop, until the required size is reached. The torch is the most important factor in autogenous welding and cutting. The type generally admitted to be of the best construction consists of two small pipes or conduits terminating at one end with hose connections, the other entering a recess head that receives the torch tips. The pipe for acetylene is screwed into a cylinder about one and one-half inches in diameter, which serves for a handle, and is packed in porous material that prevents the possibility of communicating a flame beyond that point.

Torches for Welding.—It is not generally known that three distinct types of torches have been invented for oxy-acetylene welding. These are termed respectively low, medium and high pressure, taking their name from the relative pressure under which the acetylene is used. The high pressure torch was never introduced into this country owing to certain disadvantages, finally causing the medium pressure torch to be brought out. The low pressure torch was invented by Edmond Fouche, and its principle is based on that of the injector, the acetylene being drawn by suction produced by the flow of oxygen, which is under pressure. The acetylene is brought to the torch under a pressure of a few ounces per square inch only. The flow of oxygen is regulated by the area of a nozzle and by its pressure so that the correct proportion of acetylene is sucked in. The mixture then passes out at the burner or tip of the torch.

The size of the orifice in this tip is of great importance, as it controls the resistance in the mixing chamber to the flow of oxygen, and therefore controls the proportion of the two gases. As is well known, the amount of fluid sucked by an injector is proportional to the square of the velocity of the propelling fluid. It is therefore essential that the flow of oxygen should not vary or the proportion of acetylene would not be constant. For the low pressure torch this proportion is 1.7 oxygen to 1.0 of acetylene by volume, at atmospheric pressure and any variation in either direction will produce either an oxidizing or carbonizing flame. The flame should, therefore, be carefully watched as the orifice in the tip may be expanded by the heat being deflected onto the torch, or it may be

contracted by particles of metal adhering to the tip, thus changing the mixture. Owing to the fine adjustment of the injector parts, these torches are often made without any means of varying the size of the flame, it being necessary to disconnect the torch from the hose and substitute another one, when it is desired to do this, a number of torches being required if it is necessary to weld on all classes of work. Owing to the low pressure, the speed of the

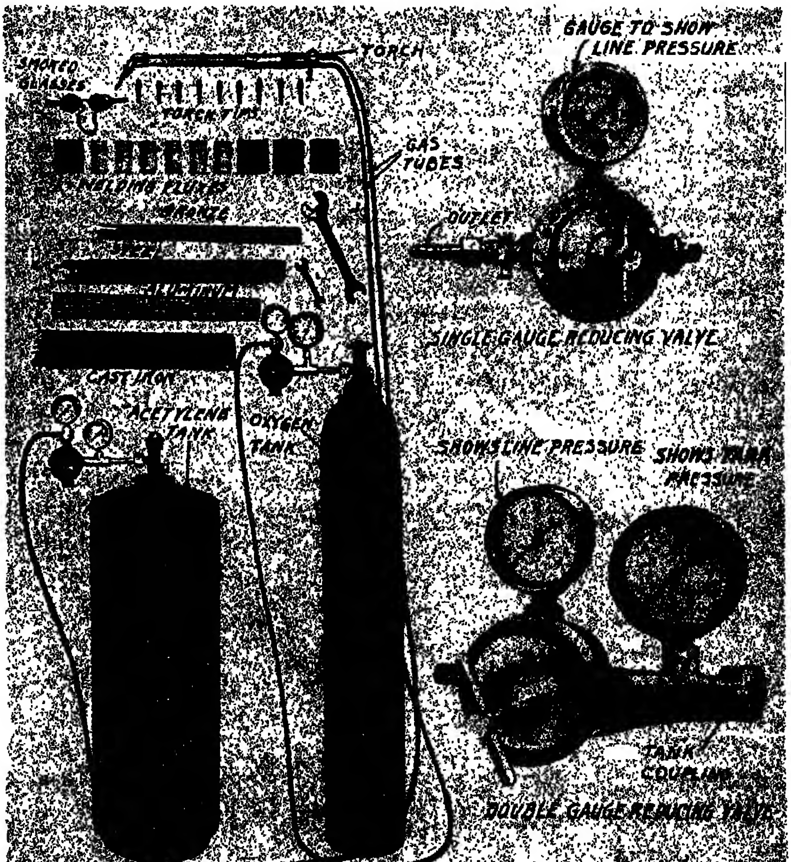


Fig. 452.—Complete Welding Outfit Suitable for Repair Shop Use. Note Appearance of Automatic Reducing Valve.

issuing mixture is very little above the speed of the propagation of the flame and "back fires" frequently occur; the gas has then to be turned off, lighted again and the mixture readjusted. The ordinary acetylene lighting generator supplies gas at a pressure suitable for use with this torch.

In the medium pressure torch, both the acetylene and oxygen are under an appreciable pressure, which results in a constant mixture under all conditions, the proportion being 1.00 of acetylene to 1.3 of oxygen. The mixture is regulated by holes at the inner end of the detachable tip, and is not affected by any variation at the outer orifice. The pressure of each gas is kept constant as required by adjustable reducing valves in the pipe lines. The speed of the gas is greater than in the low pressure torch and back firing is practically eliminated. If the flame goes out, it can be relighted without altering the gas adjustment.

Sources of Gas.—The source of oxygen and acetylene gas supply is a question which requires careful consideration for each individual case separately. It can either be generated at the plant, or can be shipped in steel cylinders from one of the several companies who are generating and compressing it.

The points to be considered are:

1. The transportation charges for the compressed gas and cost of the cylinders.

2. The quantity of gas used and, therefore, the number of cylinders that would be required to contain it.

3. The regularity of the consumption, depending on the regularity of the work, and also of its size.

4. The cost of generating the oxygen at the plant.

The first depends upon the locality and shipping facilities, as well as in the quantity of gas that will be used. The second also depends on the first, with the consideration that the cost of cylinders might equal or exceed the cost of the generating plant.

The third might necessitate the generation of oxygen at the plant, anyway, particularly if repairs were the principal work carried out as unless the supply of work were regular and all of small size, one could not depend on keeping a sufficient supply of oxygen on hand, and this class of work is generally required im-

mediately, and cannot therefore wait for shipments. The fourth depends on the quantity of the chemical that could be bought at a time and the cost of its transportation, and also on the amount of establishment charges that would be figured in.

It will be evident that the best method for the garage repair shop is that which involves the least expenditure as the amount of

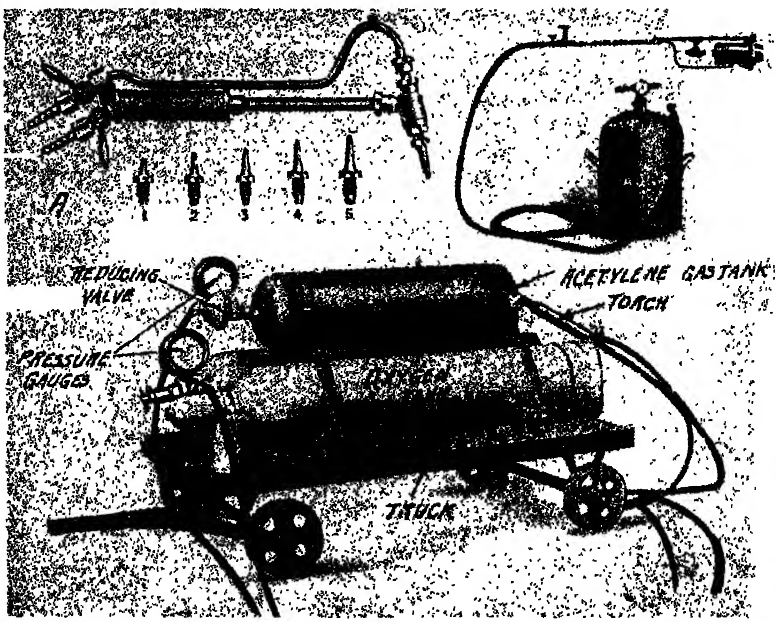


Fig. 453.—Torch for Autogenous Welding and Tips for Same at A. Preheating Torch at B. Portable Welding Outfit on Wheeled Truck Shown at Bottom of the Illustration.

work done would not be sufficient to warrant the installation of an oxygen generating plant using the usual mixture of chlorate of potash and manganese dioxide. The acetylene gas may be readily obtained through the almost universal Presto-lite service and oxygen cylinders are also easily available.

The matter of cost of welding by the oxy-acetylene process depends upon many factors, and estimates can only be given by the

repairman after he has had considerable experience with the process. Some work requires preheating and careful manipulation, some must be clamped to prevent distortion, in such cases the cost of the jig or fixture is apt to cost more than the welding.

CAPACITY OF CYLINDERS

All cylinders are charged at 150 lbs. pressure

Diameter Inches	Length, Inches	Capacity, Cubic Feet	Weight, Pounds
7	24	50	50
8	30	80	75
10	30	125	105
12	36	225	120
14	48	400	349
16	48	500	435

The following table gives an approximate idea of the cost of welding under the conditions stated:

APPROXIMATE COST OF OXY-ACETYLENE WELDING

Oxygen at three cents. Acetylene at one cent per cubic foot. Labor at 30 cents per hour.

Tip No.	Thickness of Metal	Consumption of Acetylene per Hour	Consumption of Oxygen per Hour	Linear Feet Welded per Hour	Cost of Labor per Hour	Total Cost per Hour	Cost per Linear Foot
		Feet	Feet	Feet	Cents		
1	$\frac{1}{32}$ to $\frac{1}{16}$	2.8	3.6	50	30	$0.43	$0.008
2	$\frac{1}{16}$ " $\frac{3}{32}$	4.5	5.7	30	30	0.51	0.017
3	$\frac{3}{32}$ " $\frac{1}{8}$	7.5	9.7	25	30	0.66	0.026
4	$\frac{1}{8}$ " $\frac{1}{4}$	11.7	15.0	16	30	0.86	0.045
5	$\frac{1}{4}$ " $\frac{5}{16}$	18.0	23.0	10	30	1.17	0.117
6	$\frac{5}{16}$ " $\frac{7}{16}$	25.0	32.0	7	30	1.51	0.216
7	$\frac{7}{16}$ " $\frac{1}{2}$	32.5	41.5	5	30	1.87	0.374
8	$\frac{1}{2}$ upward	48.5	62.0	..	..	2.64	.....

Instructions for Operating.—The following instructions are taken from the literature of the Welding Apparatus Company of

Toledo, Ohio, and while intended to apply to the "Monarch" welding outfits manufactured by this concern, the processes may be followed with almost any of the garage type welding outfits offered by reputable manufacturers.

1. See that all gas connections are tight, using soap suds to discover leaks, if any.

2. Upper side of torch is for oxygen. Acetylene connection should be made to lower side of large handle.

3. When all connected up ready to light torch, turn regulators out, so there is no tension on spring and they are closed. Then turn both tank valves open full. Open both valves on torch one full turn or more; turn on acetylene slightly and light at tip; then turn on more until blaze has left tip slightly; then turn on oxygen same way until small white inner cone is formed in blaze. If blaze pops and goes out this denotes that not enough acetylene, or too much oxygen, is being used. The flame should have a small inner cone from ¼ inch to ½ inch in length with an outside flame of larger proportions.

4. Welding should be done at the end of the small white cone.

5. In case there is a faint outline of a larger cone, the acetylene tap should be closed slightly, which will bring this cone just inside the small white cone, producing a neutral flame proper for a successful welding. (Opening oxygen will give same result.)

6. Blow pipes are adjusted for the proper working conditions and no sharp instruments should be used to clean out the welding tips.

7. Practice should begin on lighter sections of metal and gradually work up to the welding of the heavier sections.

8. When working on heavy work, water should be provided in which to cool the welding tips. Leave the oxygen tap open to expel steam formed. Do not plunge, but dip several times to gradually direct the heat to the tip. Otherwise you may crack the welding head.

Welding Cast Iron.—In welding cast iron, such as automobile cylinders and machinery parts of similar character, it is necessary to preheat the part which is to be welded to a temperature which is slightly below a dull red heat, if there are no parts that will be

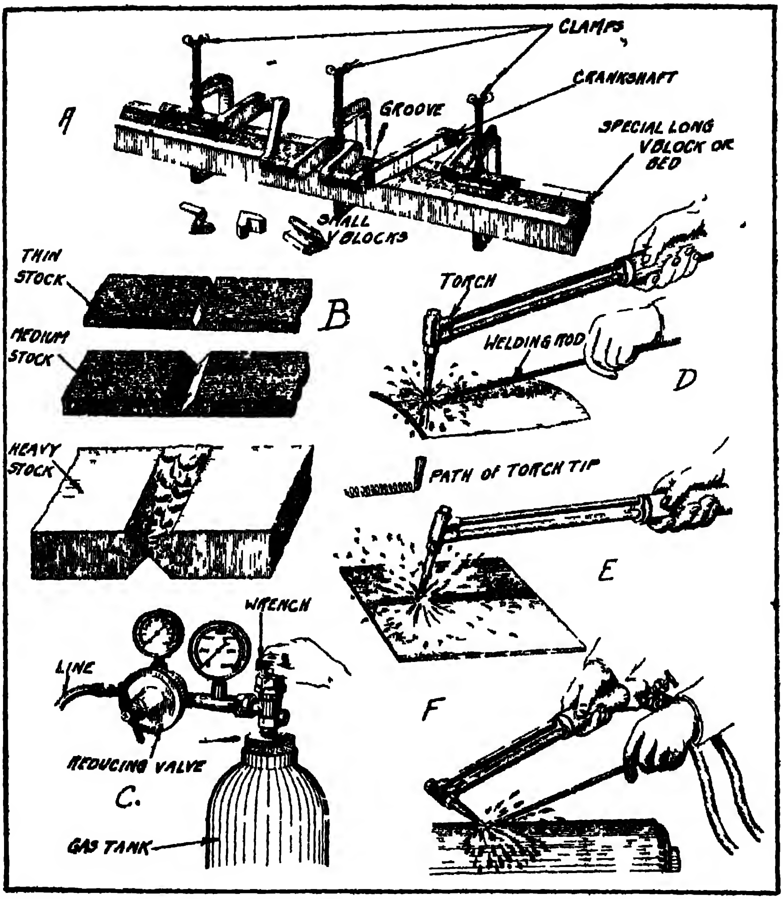


Fig. 454.—Illustrating Various Steps in Autogenous Welding Operation, Such as Preparation of Work and Manipulation of Torch. A—Method of Holding Crankshaft When Welding Broken Web. B—Forms of Grooves for Welding Various Thicknesses of Stock. C—Showing Method of Attaching Reducing Valve to Gas Tank. D—Method of Using Welding Rod. E—Showing Path of Torch Tip. F—Filling a Hole by the Autogenous Welding Process.

injured by such heat. This heat should be applied gradually and when the whole object has been sufficiently preheated, the welding can be done. There are two reasons for preheating. First, to save

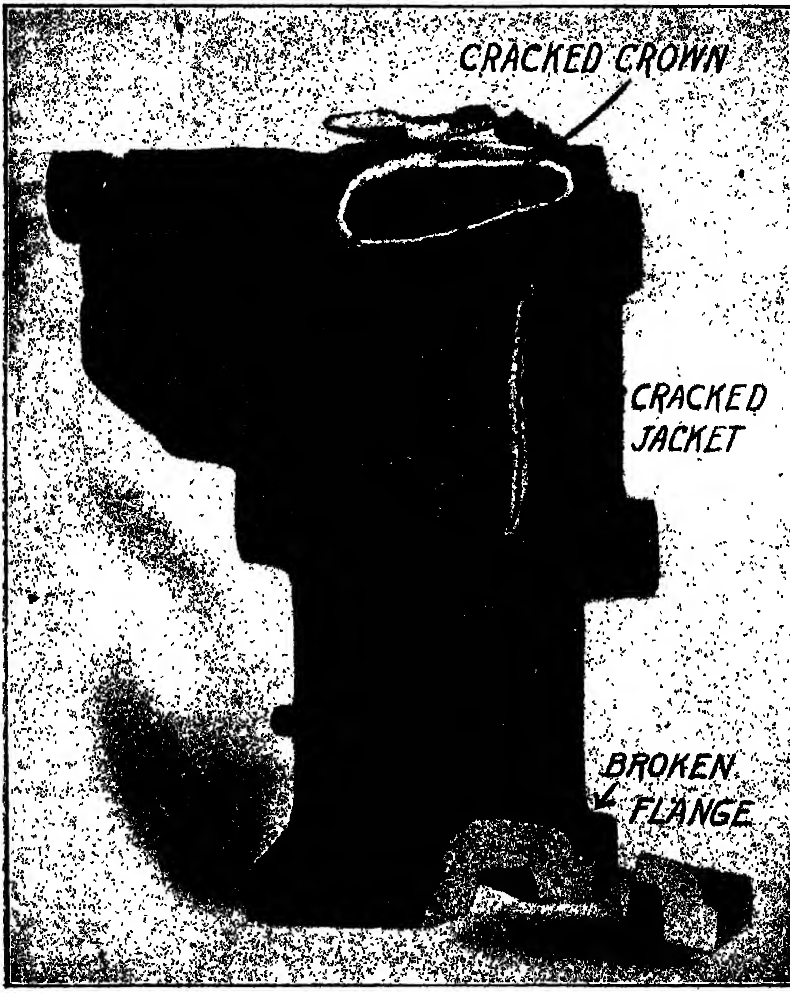


Fig. 455.—Illustrating Principal Cylinder Defects that May be Readily Repaired by Autogenous Welding Process.

gas, and second, to relieve strains, due to uneven expansion and contraction of the part being welded. Great care should also be used to see that all castings cool slowly after welding, as many a good weld has been spoiled by too rapid cooling. A box of lime

or ashes should be provided in which to bury the casting so it will cool slowly.

Method of Preheating.—Where city gas of some kind, together with compressed air, are both obtainable in the shop we recommend very highly a preheating blow pipe using this fuel. It makes an ideal outfit and in fact will be found just as efficient as the other preheaters herein shown, and will answer any and all purposes

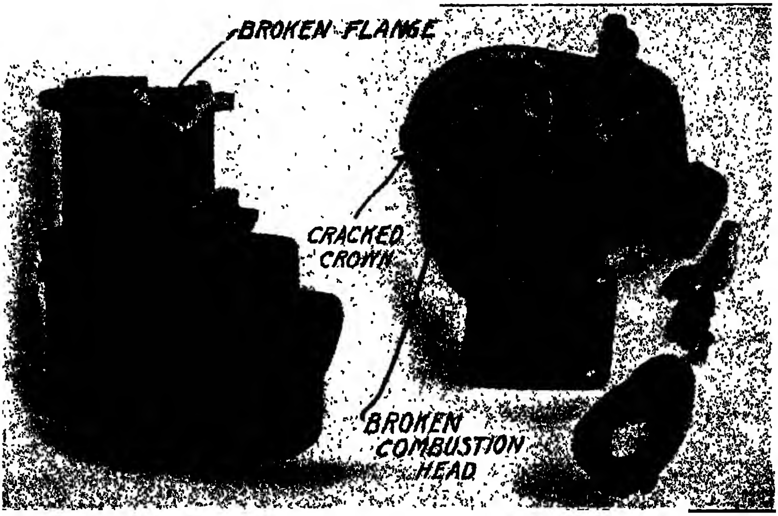


Fig. 456.—Examples of Defective Cylinders that Were Repaired by Autogenous Process. Cylinder Flange at the Left was Repaired at a Cost of $7.50; Cracked Crown and Water Jacket at the Right Repaired at a Cost of $12.

to which the oil burning preheaters might be applied. Of course, where fuel gas and air are not both obtainable in one shop we recommend the oil burning outfit shown, although they are slightly higher in price, but, as stated above, where the shop is so situated as to be fortunate enough to have both compressed air and fuel gas of some kind the gas preheating torch will be found to be very satisfactory, as the first cost, and also the cost of maintenance, is low. The furnace or muffle is then built of fire brick to a suitable

size for the particular part we are about to weld. A removable cover is used of asbestos board or sheet metal.

After the welding has been done, the object should be heated again in a similar manner as the preheating was done and then allowed to cool off slowly in the muffle. This is necessary to prevent cracking due to the local expansion and contraction, caused by the local heat of the welding flame. This method is also useful in obtaining a softness of the material in the weld. This method of handling welding of cast iron will prove a saving of from 30 to 50% of the cost of gases used for welding. There is nothing particularly difficult in the handling of the welding flame in connection with welding cast iron, but it should be borne in mind in welding of heavy sections, that the fractured portions should be tapered out in order that the welding can be commenced at the center of the section, building up as the welding proceeds. A flux is necessary for use in welding cast iron and will be found to make the metal flow more readily and at the same time, flux out the sand, dirt, grease, etc. Be sure that the sides of the fracture are in molten condition before filling material is added.

Welding Aluminum.—The welding of aluminum requires considerable skill and experience before successful work can be expected on intricate parts. The manner of making the weld is slightly different from that used with welding of cast iron, due to the fact, that when aluminum is heated, an oxide film is formed, which prevents the metal running together and forming a suitable weld. To overcome this, the aluminum filling rods must be inserted into the molten aluminum, which is being welded, and moved about rapidly, something similar to puddling, in order to break up this oxide film and allow the aluminum to run together. A flux has also proven of advantage in this connection, where before, practically all of this work was done without the use of a flux. A larger tip is necessary for welding a section of aluminum than would be required for the same section of steel or cast iron. This is due to the fact that aluminum conducts heat away very rapidly. With the proper size tip in use, it is necessary to melt a considerable portion of aluminum, which is being held in shape by the fire clay form. Now the extra metal can be added from the filling rod and

stirred or puddled with this rod to break the oxide film which forms when aluminum is melted. A flux has been provided for use in this connection and will be found very valuable for breaking up this film. In fact, by using this flux, bosses can readily be built up at any desired point. This is something that could not be done before a flux for welding aluminum came into general use.

All precautions should be taken to have the work securely fastened or harnessed, for instance, when welding a hole in the

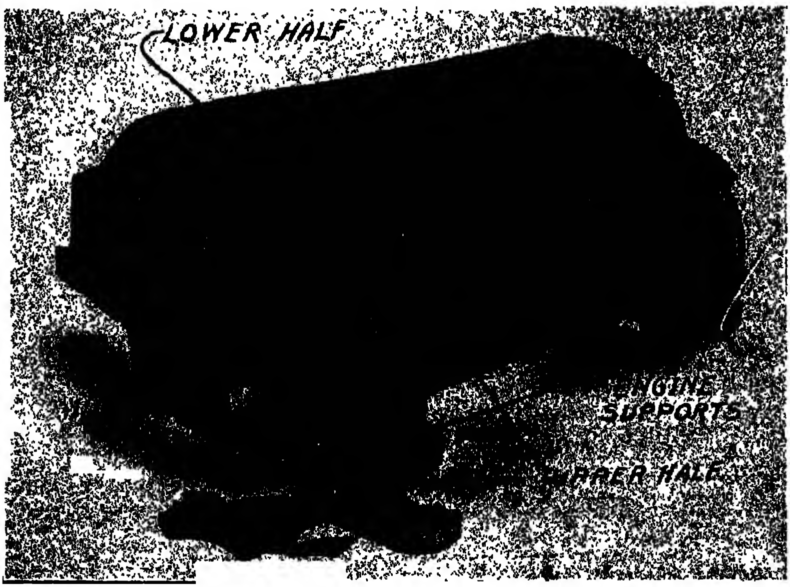


Fig. 457.—Example of a Broken Crank Case Repaired by Autogenous Welding Process at a Cost of $35.

side of a crank case, it is customary to clamp a shaft, which approximates the size of the bearings (plus, of course, the thickness of the cast metal bearings, which would melt out when preheating,) into the crank case bearing supports, in order to insure perfect alignment of the bearings. Angle irons are bolted to the flanges where connection is made to the other half of the crank case in order to insure perfect alignment of this part.

It is good practice to place a sheet of paper on the inside of the case next to the crack to be welded. This paper prevents the fire clay from getting into the crack. Upon this is placed fire clay in plastic condition which is held in place by means of asbestos fiber. This makes a light backing or mold for the case and can be easily handled without fear of the mold or core being so heavy as to break down the case when heated for welding. This mold should be large enough to cover sufficient area around the crack so that the aluminum will not break down.

Aluminum parts must always be preheated and handled in a similar manner as automobile cylinders, as outlined before, with the exception that aluminum, of course, should not be heated to such a high temperature; on account of the fact that within 50 degrees C. of the melting point, the metal is very brittle and without strength. It is customary to heat up these cases thoroughly until they will melt half and half solder in wire form. This temperature is about right to prevent cracking occurring on account of expansion and contraction and at the same time, the aluminum will possess sufficient strength so that with ordinary handling no trouble is experienced with alignment or failure of the part.

Welding Malleable Iron.—Parts of malleable iron are handled in much the same manner as cast iron parts in preparation for welding. It is customary to re-enforce the malleable iron weld as much as possible by building up the section at the fracture. The filling material used is usually nickel steel in the bottom of the weld, finishing the top surface with cast iron rod. The latter runs better and makes a smoother finish.

In some instances you may find that the fracture will be through a tapped opening, in which case, it will be necessary to cape this portion out entirely, making a much larger opening than the hole itself and then filling this with cast iron, using the same precaution in welding cast iron to have this portion soft. Wherever the union is made between filling material used and the malleable iron, you will find this so hard that it will be impossible to drill or machine in any way except by grinding.

In some cases in making repairs on malleable iron parts, it is even necessary to strap these parts by means of wrought iron or

steel straps welded to the body of the casting. In any event, bear in mind that the heat necessary to melt the malleable iron will destroy the properties of the malleable iron, which were put into the part when annealed in the furnace. Consequently it is necessary to use a stronger filling rod and increase the section.

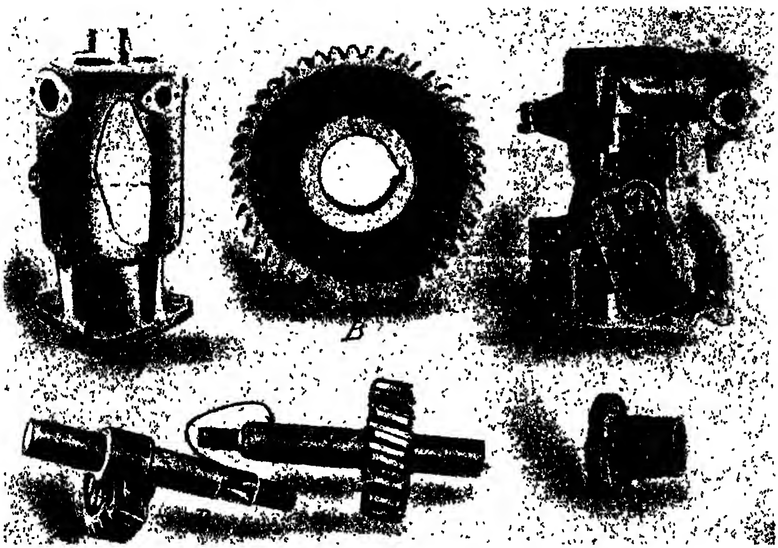


Fig. 458.—Examples of Repairs Accomplished by Autogenous Welding Process. A—Cracked Water Jacket Restored at a Cost of $6.50. B—New Metal Applied to Replace Broken Teeth on Transmission Gear at Cost of $1.50. C—Cylinder Water Jacket Repair Costing $12. D—How Worn Keyway on Steering Sector was Filled with New Metal for Recutting at Cost of $1.25. E—How Worn Special Steel Bushing was Restored to Efficiency by Filling Grooves with Metal at Cost of $1.25.

Welding Brass and Bronze.—The preparation of brass and bronze castings for welding is similar to that for cast iron castings. The fracture must be caped out so that the welding can start at the center, the groove being filled with metal melted from filling rod. The filling rod should be of approximately the same mixture as the part to be welded. Brass should never be used as filling

material for bronze castings, and a strong weld expected. Powdered borax or boric acid may be used as a flux. A mixture of ½ borax and ½ boric acid gives good results. In welding brass or bronze the work is carried out as for welding cast iron. The metal surrounding the groove is melted and the filling material added, drop by drop, as it is melted from the rod. Be sure the metal of the casting is in a molten condition, otherwise an imperfect weld will result. Brass welds can be easily spoiled by burning the zinc out of the composition. Care should be taken not to heat beyond the melting point. Flux should be used freely. If the welded portion has been burned, it will be exceedingly porous.

General Hints.—Be sure the welding flame is neutral. Be sure the part to be welded is set up properly. A poor set up may spoil the best weld for practical use. Proper heat treatment before and after welding is as important as good welding, when intricate castings, such as cylinders and crank cases are being repaired. Avoid hard spots in cast iron welds by preheating before and annealing afterward. Take care in using sufficient heat in welding and do not make the union between casting and filling material too sharp and defined. Do not allow drops of metal to fall on partially molten metal. Use the best grade of filling material. The best are none too good when all the expense of the repair may be lost by a weak weld. When preheating aluminum castings for welding, do not attempt to heat in one place only. Keep the burner moving to spread the heat uniformly. In welding steel be careful that the metal above the weld does not weld together and leave a space that is not welded. A "V" shaped groove will prevent this. The accompanying illustrations show clearly the apparatus and method of manipulating the torch in doing various classes of repair work, also some typical automobile parts that can be saved by the welding process and cost of accomplishing the work. The photographs of automobile parts were furnished by Henry Cave, of The Welding Company, Springfield, Mass., one of the leading authorities on this subject.

Treatment of Steel, Annealing.—Many varieties of steel are hard when the process of manufacture, especially if rolling or hammering is involved, is completed, these being principally tool and special metals. In order that they may be worked without

too much trouble by ordinary machine tools it is imperative that they be soft, and this condition is obtained by a process known as annealing. While steel can usually be bought annealed cheaper than it can be treated at the factory or shop where it is to be machined, sometimes conditions materialize that make it necessary to anneal metal to facilitate work and to reduce stresses upon the machine which completes the finished product. This process not only makes the steel softer, but also removes the internal strains, or the tendency of the metal to crack and spring when hardened. The strains are caused by the rolling or hammering processes in the steel mill or forge shop. When the metal is a forging or blank of nearly finished size, it is customary to remove part of the surface by taking several rough cuts, after which the piece is ready for annealing. In order to soften steel it is necessary to heat it to a uniform red heat and allow it to cool slowly, which process can be carried on by several methods.

Box Annealing.—The method commonly followed when the pieces are of large size is known as box annealing, and for this treatment it is necessary to have an iron box and furnace of sufficient capacity, as it must be obvious that to do this work in a manner commercially practicable it will be essential to treat a considerable quantity at the same time. These are placed in the container and packed in wood charcoal which has been ground or pounded into small pieces. A layer of this material is first placed on the bottom of the box to a depth of an inch, and then follows a layer of the steel, then another layer of charcoal, then more steel and so on.

The pieces of metal should not come within a one-half inch of each other or within an inch of the walls of the container at any point, and the spaces should be filled with charcoal, the metal being covered with another layer of packing material about an inch in depth. This method of packing is repeated until the box is filled, care being taken that all pieces do not touch each other or the iron walls. A tight-fitting cover is then applied and the seams are sealed, to exclude the direct heat of the furnace, by fire-clay. Several test wires are placed through the top of the box, which are withdrawn from time to time to see if the contents are of the

proper temperature. The heat should be maintained a sufficient length of time to insure a uniform temperature, and the color of the pieces should not be allowed to go over a full red. After the box and contents have been maintained at the desired temperature for the proper length of time, the heat is shut off and the whole allowed to cool slowly, the metal being left in the container until cold.

Two Simple Methods.—Often in shops there are no facilities for box annealing and other methods may be used, though the

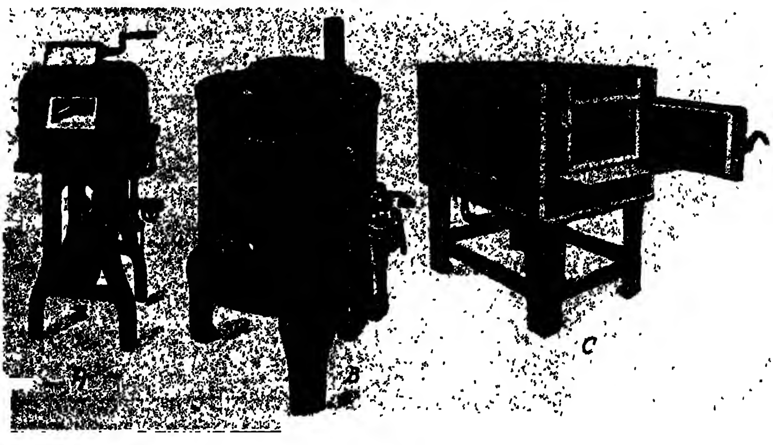


Fig. 459.—Examples of Heat Treating Furnaces. A—Hardening Furnace. B—Lead Pot Furnace for Tempering. C—Carburizing or Case Hardening Muffle

work is not so uniform as by the treatment previously described. In one of these, the metal to be treated is heated in a forge or furnace until a uniform red, and then placed on a piece of board in an iron box, the wood resting upon a bed of ashes several inches deep. A second piece of board is placed on the pieces, and the whole covered with ashes. The pieces of wood will smoulder and maintain the metal at a high temperature for some time. Another common method of annealing is to heat the pieces to a red heat and merely bury them in ashes, which is apt to give unsatisfactory results unless the ashes are also heated which can be easily accom-

plished by burying a large piece of heated iron in the annealing box. When the steel has been sufficiently raised in temperature this piece of iron is removed and the steel part buried in its place. The whole secret of successful annealing is to gradually heat and cool the metal to be treated; and the more gradually and uniformly the temperature rises and falls, the better the character of the work.

Hardening.—After the parts have been machined to the finished or nearly finished size, approved practice is further heat treatment to either toughen or harden the steel. The amount and character of treatment depend largely upon the use for which the piece is intended and the composition of the material. Steel may be hardened by several processes, the most common of which is raising it to a low red heat or dull cherry red and plunging it in some cooling medium such as water, brine or oil, or by case hardening, which merely acts on the surface of the metal.

Steel should never be heated to a temperature greater than required to give the desired result, and the degree varies with the composition of the steel as relates to the carbon content, the size and shape of the piece and the purpose for which it is to be used. Much depends upon heating uniformly; the edges and corners should be no hotter than the center and the interior should be of the same temperature as the surface. If this precaution is not taken the metal may crack in the cooling bath, because uneven changes take place in the molecular structure. If heated in an ordinary forge be sure that no air from the blast strikes it, which wi l prevent uniform heating. When uniformly heated it should be plunged in a bath to give it proper hardness. It must be worked up and down rapidly in the bath to prevent the film of steam forming, which would surround it if kept in one position and prevent proper contact with the cooling fluid. If the piece is long and slender it must be moved up and down, but if short and with teeth on the outer edge, as a milling machine cutter it should be agitated rapidly that all teeth will be cooled uniformly. If it is flat and has a hole through it, the walls of which must be hard, it should be so moved that the liquid of the bath passes through the aperture and at the same time strikes both faces. Tool steel should always be hardened

at a temperature (about 1350 to 1450 degrees) which leaves a fine grain when the piece is broken, which can be determined by hardening and breaking a small piece from the same bar as the part is to be made. A coarse grain denotes a higher temperature than is permissible. An excellent bath for hardening small pieces is made by dissolving one pound of citric acid crystals in one gallon of water. The container should be tightly closed when not in use to prevent loss by evaporation.

HEAT DETERMINATION BY COLOR

Degrees F.	Degrees C.	Color of Heats	
752	400	Red-visible in the dark.	Tempering.
885	474	Red-visible in twilight.	Tempering.
975	525	Red-visible in daylight.	Tempering.
1077	581	Red-visible in sunlight.	Annealing.
1292	700	Dark red.	Annealing.
1472	800	Dull cherry red.	Hardening.
1652	900	Cherry red.	Carbonizing.
1832	1000	Bright cherry red.	Carbonizing.
2012	1100	Orange red.	Forging.
2192	1200	Orange yellow.	Forging.
2372	1300	Yellow white.	Forging.
2552	1400	White-welding.	
2732	1500	Brilliant white.	

Pack Hardening.—Pack hardening is the method employed with pieces that cannot be treated by the ordinary processes without risk of springing or cracking them. The article is packed in an iron box with some carbonaceous material and subjected to the action of heat to cause it to absorb enough carbon to enable hardening in an oil bath. While this treatment is not generally used it is suitable for a number of different tools, such as milling cutters and taps or dies which must be hardened without altering the diameter or pitch. The usual material employed is charred leather which is mixed with an equal quantity of wood charcoal, both materials being reduced to particles about the size of a pea, or smaller. The pieces are placed in a container and packed in the manner as for box annealing, and as is the case with that process it is just as cheap to treat a number of pieces as it is one, providing the box be of suffi-

cient capacity. The pieces should be wired with ordinary iron wire of sufficient size to sustain the weight of the piece when heated, and one end of the wire should be covered with a luting of fire clay. Several holes should be drilled in the cover for test wires.

The box is placed in the furnace and heated sufficiently (about 1650 to 1700 degrees) to charge the parts with carbon, which varies with the character of the parts treated. For instance with a piece of one-half inch diameter or under the heat is maintained for about one and one-half hours, while pieces from two to three inches in diameter must be heated for two and one-half to four hours after the parts have become red hot. When the box has been maintained at the required temperature for the correct period, it is removed from the furnace and the cover taken off. The parts are then removed by means of wires attached to them and immersed in a bath of raw linseed oil. They should be moved about in the liquid until the red has disappeared and are then lowered to the bottom and allowed to remain immersed until cold. When a piece of steel one inch in diameter or larger is hardened, it should be immediately reheated over a fire after cooling, to prevent cracking, which would be caused by molecular changes which take place after the outer surface is hardened and unable to yield to unequal strains. Reheating the surface to a temperature of about 212 to 300 degrees Fahrenheit will accomplish the desired result without materially softening the steel.

Tempering.—The hardening of a cutting tool makes it too brittle to stand up well in use, and consequently it is necessary to soften it somewhat. This operation is known as drawing the temper and is accomplished after the part has been quenched by reheating to a proper temperature, which is ordinarily determined by the color on the surface of the tool, which must be brightened previous to this operation. As the metal is raised in temperature a light, delicate straw color will appear, and then in order, as deep straw, light brown, darker brown, light purple, dark purple, dark blue, light blue, blue tinged with green and black. When black appears the temper is gone. These colors furnish a guide to the temperature and condition of the hardened steel. A table pre-

HEAT TREATMENT OF HIGH-SPEED STEEL TOOLS

Kind of Steel	Method of cutting off unannealed bars	Forging Heat	Hardening heat, Cooling medium, temper and grinding: Lathe and Planer Tools, etc.: Temperature	Cooling medium	Condition of wheel used for grinding	Taps, Milling Cutters, etc.: Temperature	Cooling medium	Temper required	Directions for Annealing: Packing and packing material	Time required for heating	Temperature required	Manner of Cooling
Burgess No. 4 and No. 5	Cut off hot	Even cherry red	White welding heat on point	Cold air blast or fish oil †	Dry wheel (grind slowly)				3 parts sand 1 part lime	2 to 3 hours	Bright red	Very slowly
Ark	Cut off hot	Canary color	Fusing heat on point	Cold air blast or thin oil †	Very wet wheel	Light yellow heat	Oil †					
Midvale Special Self-hardening	Nick on wheel, Break cold	Dull orange	White heat	Cold air blast		Dark cherry heat, then heat in white hot lead	Oil, cool until color disappears		1 part lime 1 part charcoal		Light cherry red	Slowly
Capital High-speed		Full bright red	White heat	Cold air blast	Wet sandstone	Full white heat	Cold air blast	No temper	Heat in air-tight box lined with fire-brick	1 to 4 hours	1650° F	Very slowly
Heller's Alloy High-speed		Bright yellow	Bright yellow heat	Air blast or fish oil †	Wet stone	Bright yellow heat *	Air blast †	Temper seldom required	Powdered charcoal Air-tight box		Bright yellow (2000° F)	Slowly
Blue Chip		Cherry red	Clear white heat on point	Air Blast or oil	Dry wheel	White heat just below fusing	Oil	Straw color	Lime Air-tight box		Bright red or dark yellow	Very slowly
Allen's Air Hardening		Bright red	White heat on point	Cold air blast or water at 150° F.	Wet stone				Lime Air-tight box		Bright red	Very slowly
Bethlehem Self-hardening	Cut off hot	Between bright cherry red and full yellow	White heat on point	Dry, cold air blast		As hot as possible without fusing	Oil		Heat and bury in lime		Bright cherry red	Slowly
Rex High-speed	Cut off hot	Bright red	Fusing heat on point	Cold air blast (cool until tool can be held in the hand) †	Wet or dry	As hot as possible without fusing	Oil †	Temper if necessary	Charcoal, lime, or sand, air-tight box	2 to 8 hours	Full red	Very slowly
Novo	Cut off hot	High lemon color	Fusing heat on point	Cold air blast or running lard or fish oil †	Wet wheel (grind slowly)	Red heat, then white heat in furnace	Thin fish or cotton seed oil †	According to use of tool	Lime in air-tight box	12 to 18 hours soaking heat	Full red	Very slowly
Bohler's Styrian High-speed	Nick hot, break cold	Bright yellow	White heat, (not fusing)	Cold air blast		White heat, just below fusing	Fish oil		Charcoal Air-tight box	4 to 6 hours	1830° F.	Slowly *
Mc Innes extra High-speed		Full red	Fusing heat on point	Air blast or fish oil	Dry stone	Light cherry red heat	Air blast or fish oil		Ashes or lime, air-tight box		Cherry red	Slowly

Note If common forge is used for heating, have a deep fire, plenty of coke and light blast. In general, oil, gas, or coke furnace is preferred. * Do not use gas fire. † While steel is hot, it must not be dipped in water.

Contributed by Ethan Viall, MACHINERY'S Data Sheet No 117.

sented herewith gives the color and corresponding temperature at which the various tools mentioned are best quenched. When work is tempered in large quantities the above method is expensive, and is not as reliable as when the articles are heated in a kettle of oil, using a thermometer for indicating the temperature. A piece of perforated metal is used to keep pieces away from the bottom of the kettle, though a wire basket will serve the purpose even better. As soon as the parts are raised to the required temperature they are quenched to harden.

Case Hardening.—When an article of wrought iron or low carbon steel is to have a hard surface it is not possible to treat it by merely quenching, as there is not enough carbon in the steel to insure proper hardening. The process of treating such materials is known as case hardening and consists of covering the surface while red hot with some material which forms a coating or case steel, which can be hardened by quenching, as in previous processes. Small parts. such as nuts, bolts, cones, etc., may be case hardened by heating red hot and covering with a thin layer of powdered cyanide of potassium, and when this melts, the article is again heated to a red heat and plunged in water. While the above process is suitable for hardening a few small pieces it is not recommended for large quantities of work, as the results would not be uniform and the process would be too expensive. If many small pieces are to be case hardened at the same time, they may be treated in much the same manner as in box annealing. Granulated raw bone, and granulated charcoal should be mixed in equal proportions and a layer of this mixture placed in an iron hardening box to the depth of one or one and one-half inches. A layer of the articles to be treated is then placed in this and these are covered with more material, the same care being observed in packing and with regard to test pieces as with other processes. After the container has been sealed it is placed in a hardening furnace and the temperature maintained at a point which will keep the pieces at a red heat for periods varying with the degree of the surface hardening desired. Generally carbon will penetrate the surface of wrought iron or soft steel one-eighth inch in 24 hours, but as it is seldom necessary to harden any deeper than one-thirty-second inch, the work may be

taken out after four or five hours. With small pieces the contents may be emptied into a tank through which there is a constant circulation of water. If great toughness is required, the packing material is sifted out and the pieces immersed in oil. Large pieces must be dipped one at a time and can be wired so that they can be removed from the hardening box when desired. There has been great development of late in scientific heat treatment, though it is not within the province of this treatise to discuss these in detail, the processes which have been described being those which are of particular interest to the practical mechanic or repairman.

Distinguishing Steel From Iron.—While nitric acid has no effect upon the brightness of iron, it will produce a black spot on steel, and the darker the spot the harder the steel. Good steel, when in the soft state, has a curved fracture and a uniform gray luster, but in the hard state it is a dull silvery uniform white. Cracks or threads denote inferior quality. Good steel will not bear a white heat without falling to pieces, and will crumble under the hammer at a bright heat, while at a mild red heat it may be drawn out to a point. Iron cannot be hardened as its carbon content is too low.

Hardening Steel Tools.—One of the best, if not the best, compositions for hardening steel tools for cutting iron or wood, or even steel, is the following: To one gallon of common fish or whale oil add one pound each of beeswax and resin. When this has been thoroughly mixed by boiling and stirring, heat the steel until the scale rises a little; then immerse in the boiling oil. When cool, heat over a clean fire until cherry red, and immerse in cool oil. Resin hardens steel, whereas beeswax and tallow toughen it. If it is preferred to temper in daylight, clean the steel, polish it, and draw to the color desired.

Temperatures for Tempering.—The following table gives the required temperature in Fahrenheit degrees to produce certain colors, when tempering hardened steel:

Lathe, shaper and planer tools:

430. Very light straw.
450. Light straw.

Taps, dies and wood turning tools:

470. Dark straw.
490. Very dark straw.

Hatchets, chisels, etc.:

500. Brownish yellow.
520. Yellow, tinged with purple.
530. Light purple.

Springs, etc.:

550. Dark purple.
570. Dark blue.

Molten Metals Produce Desired Heat.—The following table gives the proportional parts of lead to one pound of tin, which when melted will have the required temperature to produce certain colors on hardened steel, by simple immersion:

TEMPERATURE

Color	F. Degrees	Proportions
Very light straw	430	1¾ to 1
Light straw	450	2⅛ to 1
Dark straw	470	2½ to 1
Very dark straw	490	3½ to 1
Brownish yellow	500	4¾ to 1
Light purple	530	7½ to 1
Dark purple	550	12 to 1
Dark blue	570	25 to 1

Working Steel and Iron.—Steel never should be kept hot longer than necessary for the work to be done, as if left too long in the fire it will lose its steely nature and grain, assuming more of the qualities of cast iron. When steel has been subjected to heat not absolutely uniform over the whole mass careful annealing should follow. Hot steel always should be put in a perfectly dry place of even temperature while cooling. A wet floor might prove sufficient to cause serious change. It is hard to make the average worker in steel believe that very little annealing is necessary,

and that a very slight change is more efficacious than a great deal. Iron heated and suddenly cooled in water is hardened to some extent and the breaking strain, if gradually applied, is increased, but it is more likely to snap suddenly. If heated and allowed to cool gradually it is softened and its breaking strain is reduced. If brought to a white heat iron is injured if it is not at the same

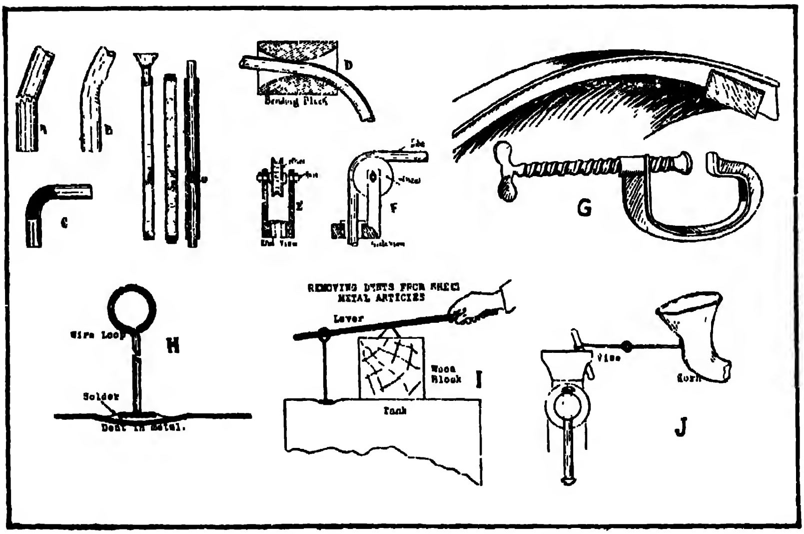


Fig. 460.—How to Remove Dents from Sheet Metal Objects and Methods of Bending Steel Tubing and Pipe.

time hammered and rolled. Case hardening bolts weakens them to some extent.

Annealing Cast Iron.—To anneal cast iron heat it in a slow charcoal fire to a dull red, cover it with about two inches of fine charcoal and spread over all a layer of ashes. It should be left until cold. Hard or chilled cast iron can be softened sufficiently in this manner to be filed or drilled.

Bending Pipe and Tubing.—Tubing is widely used in the construction of the automobile and its parts, and the repairman may sometimes desire to make a bend to replace a defective component, such as a water or gas inlet or exhaust pipe, which has become

battered and dented. Tubing is made of many materials, copper, brass and steel being the most common. It may be either hard or annealed, depending upon the use for which it is intended. The anneal or temper of seamless tubing is very important and should be carefully considered before bending. All seamless tubes, regardless of the metal of which they are made, after being cold drawn are very hard and inclined to be brittle, and have to be annealed to suit different requirements. Tubing is furnished in three different tempers—hard, medium and soft. The hard tempered is used where great strength, rigidity and stiffness are required and where the tubes are not to be manipulated in any way that would change their form. The medium temper is used where strength and toughness are needed and where only slight or medium change of form is required. The soft is used where the tubes must be manipulated and where such decided change of form is required that it demands ductile and pliable material.

A man not a mechanical expert is not expected to know the different grades of tubing, and in procuring this product the mistake is often made of buying tubing which is not suitable. A file will tell the mechanic of the degree of hardness and proper allowances are made when it is desired to make bends. Many tubes of different make are finished so nearly alike that it is difficult to determine just what will be the most suitable. The thinner the wall of the tube the more care will be necessary to make a good bend as thin-walled tubing is more liable to collapse than that with thicker walls. If a piece of hard tubing is bent without first annealing, it will break soft, as at A, Fig. 460. A piece of thin-walled tubing will collapse as at B. Some tube with a moderately thick wall can be bent without heating or filling though most now used in the arts should be filled before bending. If the interior is made solid or nearly so with some substance it can be bent to a curve of very small radius without damage to the wall, providing the tubing is properly heated and is of the right temper. Such a bend is shown at C. With a solid filling it is possible to manipulate the tube as desired, but it is not a good idea to use either a vise or wrench, or hammer and anvil for bending as the walls of the tube will suffer and the appearance of the joint be unsatisfactory at least.

Filling the Tubing.—In securing a good bend special care must be taken of the material or filling to be used as a support for the inner wall while bending. One way of filling or packing a pipe or tube for bending consists of pouring into the internal bore a molten substance, such as resin for brass and copper pipes, or a soft, low-melting point lead alloy in steel tubing. The thinner the wall the more carefully must the bending be done, and the heavier the material used for a core. The method of filling is very simple, a funnel is inserted in the tube and the molten material poured in and allowed to cool. This may be removed after the bend is made by heating the tube, which causes the substance to melt and it may be run out. A tube may be packed with clay or putty, though these substances are hard to remove from the interior after the bend is made. For hot bending the tube may be plugged up and packed with sand, which is easily removed. If the entire length of the tube is to be bent around the arc of a circle the core may be a soft iron rod, which can be removed with ease after the operation is complete as it has taken the same degree of curvature as the tube. This also permits of hot bending. The tube is inserted in the hole of a bending block or when in a fixture may be bent back over the wheel, and curves of any radius may be obtained by using larger or smaller wheels. The device is often made so that it can be clamped in a vise, though where much work of this character is done it is fastened securely to the bench. For the motorist who makes his own repairs or the experimenter the block shown is sufficient, as good work may be done with even such a simple appliance if proper care is taken in filling the tube before bending.

The pipe bending fixture shown at Fig. 461 was illustrated in the Horseless Age and is a very simple one to build, requiring only materials and tools found in almost all garages for its fabrication. With this device it is not absolutely necessary to fill the pipe with sand, resin or other material. The description will enable one to make such an apparatus. At A is shown a cast iron base about two feet square and two inches wide, cored out underneath so as to make it lighter. At B is a grooved wheel which is removable so that it may be replaced with similar wheels of different diameters for different sized bends. For instance, if the pipe is to be bent to

a 4-inch radius, a wheel 8 inches in diameter will be required. The wheel has a groove turned in its outer edge just a trifle larger than the pipe to be bent. It is made so that it will slip off and on the stud G easily. This stud is made of steel and is riveted to the base A, as shown. A follower wheel C is attached to the handle D and this is used for any bend for a given size of pipe. It will be

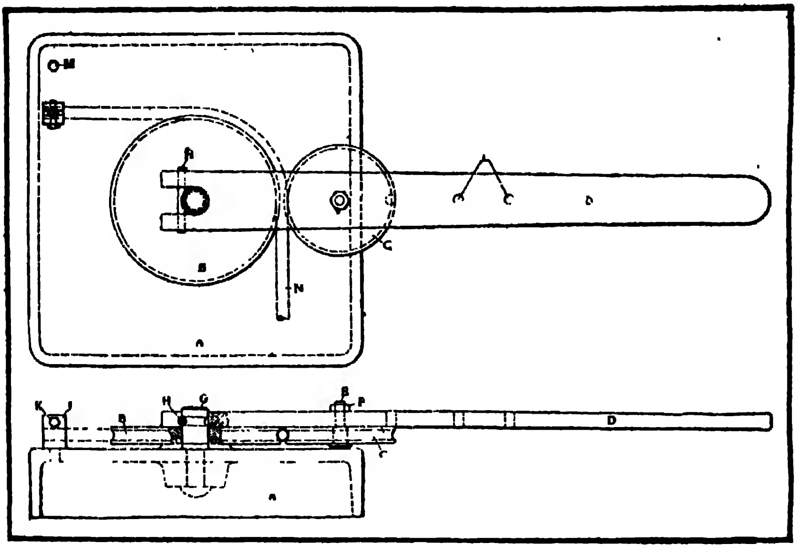


Fig. 461.—Simple Fixture for Bending Tubing Without Damaging the Walls.

noticed that the lever D has a series of holes, these being so spaced that when a different sized wheel replaces B, the wheel C can be moved out toward the end of the lever, keeping the center of the pipe N between the two grooves. The wheel C is held in place by a shoulder stud E and locked with a nut F. Since the base A has the boss finished off for the larger wheel to turn upon, the head of the stud E will clear the base when the lever arm is swung around. The stud G has a shoulder or groove cut around it, as shown in the sectional view. This is done to allow a tapered pin H to lock the arm D in place. The lever is milled out at the end, as shown

in the plan view, and a hole is drilled through both sides to take the tapered pin, which is placed so that it will lock the lever on the stud and yet allow it to turn freely. At J is shown a block machined out of rectangular stock with a round end turned on it so that it may be inserted in the base, A. A hole is drilled in this piece just a trifle larger than the pipe and a slot sawed through the hole. Then another hole is drilled at the top for a clamping bolt K to hold the pipe in place. The apparatus is now ready for use.

To bend a pipe of the size for which the block J and the wheels B and C have been made, turn the lever back 90 degrees from the position shown in the illustration. Then insert the pipe between the grooved wheels and clamp the end in the block J. Then pull the lever around to the position shown for a 90-degree bend and another 90 degrees for a return bend. The holes for the stud J are drilled in the base A on a line with the centers of the two grooved wheels, and these holes can be drilled in all four sides of the base. It is best, of course, to set up the apparatus and bend all of one size pipe and one radius at one time. After making a bend, the pin H is removed, which allows the lever to be pulled forward, carrying with it the wheel C. This leaves the pipe free to be removed after being unclamped from the block J. Sometimes a piece of pipe is encountered which is so hard that it cannot be bent easily. In this case the lever may be lengthened by slipping a length of gas pipe or other tubing over the outer end, giving a much greater leverage and particularly stubborn pieces of pipe or tube may be bent by heating several times if necessary.

Straightening Out Bent Fenders.—When the fenders become bent the usual practice is to remove them and take them to a tinsmith for repairs. This involves considerable trouble and delay. The average fender may be straightened out by taking a block of wood or a strip of metal and placing it on the damaged part as outlined at Fig. 460, G. A clamp is then attached and when screwed up the kink in the metal will be eliminated. While some of the paint will crack, the fender will present a much better appearance than if it were straightened by hammering.

Removing Dents in Tanks, Etc.—The following methods of taking out dents in hollow metal containers may prove of service

to repairmen as well as motorists in general. If the side of the fuel tank, for example, is indented, a loop can be made in a piece of stout brass wire, or a piece of bright steel rod, which is bent at right angles and soldered to the lowest part of the dented metal, as at H, Fig. 460. A larger loop is then made in the other end of the wire and with the aid of a small pinch bar and a block of wood to act as a fulcrum for the lever, the dented surface can be easily pulled flush with the surface of the tank. The base of the wooden block should be of sufficient area to prevent the side of the container becoming indented by it because of the pressure brought to bear with the lever or bar. Dents in headlights and depressions in the surfaces of horns, small tanks, gas generators, etc., can be taken out in a similar manner except that in place of the bar a stout cord should be attached to the wire loop and its free end fastened to a vise or other convenient anchorage. Fig. 460, I, shows method of repairing a tank, while J shows a sketch of a horn under treatment. The latter is grasped in the hands and a few gentle pulls will remove the dent. Obviously any other small metallic article can be repaired in the same way. The wire loop in all instances can be easily applied or removed with a blow torch or soldering iron.

No doubt more elaborate methods can be resorted to by those skilled in sheet metal working, but the writer believes that the above method is as simple as any for a piece of wire can be easily bent to any shape to suit the requirements of the job under consideration. No tools of great value are necessary, and such as are used—viz.: a length of wire and soldering iron—can be found in almost any house, and the process presented can be used to advantage with any gauge of metal generally employed in the construction of the various small articles which the motorist would attempt to repair himself.

Soldering and Brazing Processes.—Solder must be used on certain parts of an automobile, notably the radiator, the tanks and the lamps, despite the fact that such construction when subjected to stress or vibration, is not considered best. It is of considerable importance that permanent work be accomplished and in reaching this result it is necessary to bear in mind certain fundamental prin-

ciples relative to the use of solder in all classes of work. First the metal surfaces to be joined must be clean. This means in the most rigid sense. Wiping or cleaning with acid or gasoline is not sufficient. The metal must be clean, chemically, as well as free from any oxide. The best method is to use sandpaper or file the surfaces just before soldering. The surfaces must be hot—as well as the solder itself. The solder must be melted to flow with perfect free-

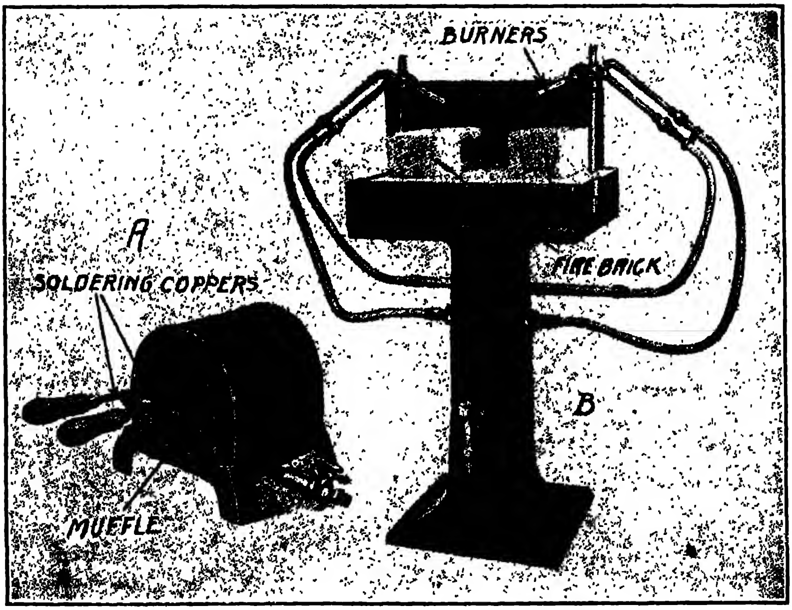


Fig. 462.—Furnace Used for Heating Soldering Coppers at A and Efficient Brazing Forge at B.

dom, otherwise it will not enter the pores of the surface to be joined. The solder must not be so hot it will burn, however. A solder bath or a soldering iron never should get red hot. It is not difficult to do a good job if the iron is large enough.

Time must be allowed for the heat to flow from the copper to the work. To prevent the solder running away the work should be held with the seam horizontal. It is impossible to hurry work of this kind, except by changing irons to keep the work hot. Most

botches are due either to imperfect cleaning or to the working being hurried through before it has been heated properly. The strength of solder is small, and its elastic limit far below its tensile strength. The area of the joint must be large. Two strips overlapping by a narrow margin are not as strong as with a wide overlap. With a lap sufficiently wide it is quite possible to make a joint stronger than any other part of the piece, not forgetting, however that a soldered joint never should be subjected to bending or other stresses which localize the strain endured by the solder. The choice of flux naturally will depend upon the work. The object of the flux is to preserve the chemical cleanliness of the metal while it is being heated and before the solder adheres. Save for the flux the hot metal would oxidize slightly on the surface and the solder could not unite with it.

If it is desired to solder two pieces which have some thickness and bulk a good piece of work cannot be done with a soldering iron, because the parts will absorb heat faster than the iron can supply it. With such work a torch must be used for sweating, heating thoroughly the parts adjacent to the intended joint and as far back as may be necessary. If the surfaces are more than one-eighth to one-quarter inch wide it is better to tin them before uniting. This is done by spreading a smooth coat of solder over the entire surface while hot. It is only necessary to press two such prepared pieces together and heat them to the proper temperature to make a perfect union. Much time is saved in sweating operations, particularly in manufacturing, by dipping the work nto a bath of molten solder. The hot solder supplies the necessary heat and the whole job is practically instantaneous. Great care is necessary to keep the bath at proper temperature. If it is too cold the work will not hold, and if it is too hot the solder will be burned and its usefulness gone. The accompanying tables will be found useful, one giving the fluxes that are best used with various materials, while the other gives the composition of solders and spelters found satisfactory for general application. The more tin there is in a solder, the stronger it is, but it is harder to melt than those having lead as a predominating element. In the case of spelter increasing the proportion of copper increases the strength:

Fluxes for Soldering.

Iron or steel	Borax or sal-ammoniac
Tinned iron	Resin or chloride of zinc
Copper to iron	Resin
Iron or zinc	Chloride of zinc
Galvanized iron	Mutton tallow or resin
Coppet or brass	Sal-ammoniac or chloride of zinc
Lead	Mutton tallow
Block tin	Resin or sweet oil

SOLDERS AND SPELTER FOR DIFFERENT PURPOSES

Solder for	Silver	Tin	Lead	Zinc	Copper	Gold	Brass
Electricians	.	1	1	.	.	.	.
Gold	2	.	.	.	1	24	.
Platinum	3	.	.	.	1	.	.
Plumbers', hard	.	2	1	.	.	.	.
Plumbers', soft	.	1	3	.	.	.	.
Silver, hard	4	.	.	.	1	.	.
Silver, soft	2	.	.	.	.	.	1
Tin, hard	.	2	1	.	.	.	.
Tin, soft	.	1	1	.	.	.	.
Spelter for fine brass	1	.	.	8	8	.	.
Common brass	.	.	.	1	1	.	.
Cast iron	.	.	.	3	4	.	.
Steel	.	.	.	1	3	.	.
Wrought iron	.	.	.	1	2	.	.
Parts by weight							

Lead Burning.—Lead burning consists in melting the metals and causing the parts to flow together and become joined without the aid of solder. It requires considerably more skill than any other form of brazing or soldering. A long step toward success may be taken by the proper arrangement of the work. It is usual to provide something which may serve as a mold or guide for the melted metal. For example, if two lead sheets are to be united by soldering, they are laid on a sheet of some non-heat-conducting substance, such as brick or asbestos. The work in the immediate neighborhood of the joint is carefully scraped so as to remove all oxide or scale which would tend to bind the melted lead and pre-

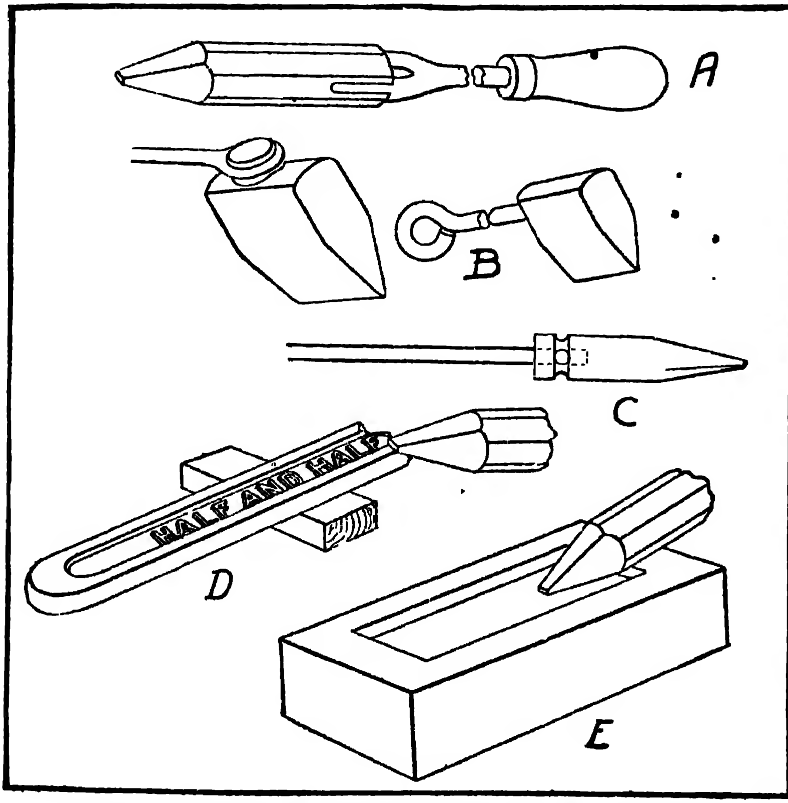


Fig. 463.—Forms of Soldering Coppers and How to Tin Them.

vent it from flowing freely. The metal at the seam is heated by a very hot bit or the flame from a blowpipe so that there is a uniform flow of lead across the seam. It is sometimes necessary to add more lead to the seam by melting a strip held in the hand. A flame of some sort is the most satisfactory source of heat for the average lead burning job, because not only is the heat more uniform, but also more intense, and the lead melts at the desired point before the surrounding metal becomes sufficiently hot to soften. There are several types of blowpipe for this purpose on the market. Some employ an alcohol flame, while others make use of mixed hydrogen and air. The flame is usually small, sharp-pointed, and

very intense. Lead burning is absolutely necessary, and is insisted upon in certain classes of work for instance, in lining tanks with lead for chemical solutions, or for joining the grids and lugs of storage batteries.

Soldering Aluminum.—Many components of the modern motor car are made of aluminum and in making repairs, if these be broken or cracked, this metal is extremely difficult to solder. While many attempts have been made to solder aluminum in the ordinary way, and even with special fluxes and solders, but little success is obtained unless the conditions obtaining are fully appreciated. Aluminum is very light and melts at comparatively low temperatures, and because of its rapid oxidization it is necessary to take great care to secure bright metal to which the solder will adhere. The alloys with which the motorist has to deal vary in proportion of alloying elements, depending upon the use for which the metal is intended the substance commonly used in combination being zinc, copper, tin, manganese, magnesium and sometimes a trace of iron. The larger proportion of any alloy is aluminum, and on the whole the soldering problem will be about the same in all cases. As must be obvious because of its low melting point, aluminum will not stand prolonged heating, a condition that may be disregarded in the case of most of the other metals amenable to soldering and brazing processes. Then again, when the critical point is reached in the heating, aluminum suddenly "wilts" and every precaution must be observed to prevent the metal becoming too hot. The following table will show the relative melting points of the common metals:

Melting Point of Metal.

	Degrees Fahrenheit
Tin	445
Lead	620
Zinc	780
Aluminum	1160
Bronze	1690
Silver	1730
Gold	1900
Copper	1930

Melting Point of Metal.—Continued.

	Degrees Fahrenheit
Cast iron	2000
Steel	2400
Wrought iron	3000
Platinum	3230

From the foregoing it will be evident that the metals of which the average solders are composed have melting points but little lower than that of aluminum, and careful manipulation will be necessary to insure heating the metal sufficiently to melt the solder, and at the same time not weaken the aluminum or cause it to flow. To successfully solder aluminum demands considerable preparation and careful manipulation, and authorities differ as to the best methods and solders to use. All agree that the metal must be dry and absolutely clean, and while this is easily said and advised it is difficult of accomplishment. If one cleans aluminum in ordinary temperatures, no matter how carefully, and obtains a bright surface, it is impossible to retain this as new oxide forms on its surface as soon as brightened. For this reason, some skilled in the arts recommend immersing the parts to be soldered in a strong solution of hydrosulphate of soda for several hours before joining them. The best solder to be used depends to a certain extent upon the alloy of aluminum, the same as with other metals. One that has been used with good success is made as follows: Ten parts each by weight of tin, cadmium and zinc and one part of lead all of which are melted together.

Dampness or salt air are the bane of the process of aluminum soldering and the rapid oxidization makes "tinning" which is of such benefit in uniting other metals, practically impossible. As moisture will hasten oxidization, the safest method of proceeding will include the drying of the surfaces, assuming that these have been properly prepared, as well as the solder, in an oven or other suitable container at a high enough temperature to thoroughly heat all parts, but lower than that required to melt the solder. When the parts are thoroughly dry, the next thing to do is to scratch the surfaces vigorously with a metal brush, bringing out the un-

tarnished metal, and removing all traces of oxide. The next step is the heating of the aluminum parts nearly to the melting point of the solder, and after applying the alloy to the surfaces, brush it into intimate relation with the surfaces, using the metal brush. If the solder does not adhere there is still some oxide on the surface, and the operation of cleaning should be repeated. When the surfaces to be joined are properly coated with solder, the rules which govern ordinary soldering work will apply, it being merely necessary to heat the surfaces, melt the solder and join the surfaces. Either a bunsen burner or blow torch can be used to heat the metal, and the important points to remember are that the work must be done quickly and that the surfaces to be joined be as clean and dry as possible, and as free from aluminum oxide as conditions will permit.

If the surface is of such a shape that it cannot be readily cleaned by scraping, it can be cleaned by dipping it into a solution of nitric acid in three times its bulk of hot water containing about 5 per cent. of commercial hydrofluoric acid. This causes a slight action on the surface of the metal as shown by bubbles. Rinse the metal after removing from the acid bath and dry in hot sawdust. There are various compounds on the market for soldering aluminum, but this operation depends more on the workman than on the solder and unless considerable experience has been had it is probably better to purchase solder than attempt making it. Zinc can be used but does not form a very strong joint. Tin can also be used, is more nearly the color of aluminum, is stronger than zinc, but is very difficult to work. A small proportion of phosphor tin added to pure tin makes it work more readily and is the basis of most aluminum solders. The chief difficulty in soldering aluminum is that the heat is dissipated so rapidly that it cools the soldering iron and furthermore aluminum oxidizes instantly upon exposure to the air. This extremely thin film effectually prevents a perfect union being made. If the parts are well heated and melted solder kept hot while the iron is allowed to stand on it, the surface can be scraped beneath the melted solder by the point of the soldering iron, thus preventing to a certain extent the oxidization. In this way the metal can be tinned. When both parts are brought to-

gether and are well tinned, they can be united with some chance of success, nitrate of silver, resin, or zinc chloride being used as a flux. A soldering tool of nickel gives more satisfactory results than a copper one as the latter alloys with the tin and soon becomes rough.

Another authority advises as follows: Use zinc and Venetian turpentine for soldering small surfaces. Place the solder on the metal and heat very gently with a blowpipe until entirely melted. Another is to clean the surfaces by scraping and covering with a layer of paraffine wax as a flux then coating the surfaces by fusion, using a layer of alloy of zinc, tin and lead, preferably in the following proportions: Zinc, five parts; tin, two parts; and lead one part. Metallic surfaces thus prepared can be soldered by means of zinc or cadmium, or alloys of aluminum with these metals. Twenty-eight ounces of block tin, three and one-half ounces of lead, seven ounces of spelter, and fourteen ounces of phosphor tin, containing 10 per cent. of phosphorus, will make a good aluminum solder. Clean off all dirt and grease with benzine, apply the solder with a copper bit, and when the molten solder covers the metal, scratch through the solder with a wire scratch brush. A good solder for low grade work is composed of tin, 95 parts, and bismuth, five parts. A good flux in all cases is either stearin, vaseline, paraffine, copaiva balsam or benzine. Small tools made of aluminum or nickel should be used in the operation of soldering. These facilitate at the same time the fusion of the solder and its adhesion to the previously prepared surfaces. Copper or brass tools should be avoided as they would form colored alloys with the aluminum and the solder. To sweat aluminum to other metals, first coat the aluminum surface with a layer of zinc, on top of which is melted a layer of alloy of one part aluminum to two and one-half parts of zinc. The surfaces are then placed together and heated until the alloy between them is liquefied.

How to Braze Steel and Iron.—As with soldering, it is important in brazing to clean the work thoroughly. Sand blasting is an ideal method of cleaning for brazing, although the work may be done with a file and emery cloth. The sand blast not only cleans the metal of all scale, but penetrates the pores, leaving it in condi-

tion to receive and hold the brass. It also costs less than the hand method. There are several compounds in the market that will make a better flux than borax, burnt and ground fine, but if wanted for a quick job, mix borax with wood alcohol, or, better still, "Columbian Spirits." Clean water is nearly as good. Mix to a thin paste and apply with a thin brush, so as to wet thoroughly every part of the joint. The flux is held in place by painting the joint with a mixture of machine oil and black lead. The joint should be pinned to hold it in place while being brazed. Run a No. 29 drill through the job and hold in place with an eightpenny wire nail. The fire should be clean, whether of gas, coal or oil. The gas fire is best, though it costs more. Put the heat on the heavy part of the work first, so as to bring it up nearly to the brazing point. When the heat is put onto the joint the heavy part will absorb it and cool off the part to be brazed. Bring it up slowly to a bright yellow heat, and as the spelter and flux begin to melt, dip the brazing wire in the brazing compound and apply to the joint. Before dipping the wire, however, it should be held in the flame so as to heat it as near as possible to the melting point and yet not melt it. As the flux and spelter melt turn the work so it will run to all parts of the joint, and while still turning remove it from the fire and keep it in motion until it sets. If it is a large job, turn off the heat and let the blast strike the work and cool it.

Nothing equals the sand blast for cleaning work after it is finished. The next best method is pickling in a weak solution of sulphuric acid and water, about one quart of acid to a barrel of water. The old-fashioned method of dipping the work in a pail of soapsuds is not recommended. Almost any broken joint in cast iron can be brazed, and if properly done it will be stronger than before breaking. To make a good job first heat the work to a dull red, taking the dirt and grease out of the pores of the metal. Next clean the work with a sand blast or with a wire brush, after which apply the flux. Fasten the broken parts firmly together, place in the fire and bring up to a bright yellow heat, in fact almost to the melting point, and apply the brazing compound. Shut off the gas and allow it to cool without moving. Brazing is possible even if the pieces are of irregular form though large work should be pre-

heated before brazing as described in speaking of the autogenous welding process.

Simple Methods of Testing Lubricating Oils.—To find if an oil contains certain solid impurities, add kerosene to half a cup of the oil until the mixture becomes quite thin. This thin fluid is now passed through filter paper or ordinary colorless blotting paper. As soon as all of the thinned oil has passed through, the blotting or filter paper is washed with kerosene. The residue that remains, if there is any, will show whether the oil contains any solid impurities. Impurities of this kind may also be determined in a coarse way by smearing a piece of common correspondence or pad paper with the suspected oil and holding it against the light. If the oil is free from solid impurities the blot of oil will be equally transparent everywhere. If not, the solid particles of sediment will be plainly visible.

To test whether an oil becomes resinous or not, it must be poured in a shallow dish, and it is then to be left for about a week in some warm place. If at the end of this period there is not the slightest evidence of a crust you may consider the lubricant to be all right. These oils may also be tested by mixing them with nitric acid. If the oil is pure, a thick mass will form in a few hours. Oils that resinify do not thus clot, but remain very thin.

Among other impurities in oils are to be found injurious acids. When acids occur in lubricating oils they destroy the parts of machines and other apparatus that they lubricate much more quickly than should be the case. A test for such impurities is found in mixing the lubricating oils with copper oxide or copper ash. These are added to the oil in a glass container. When, if the oil is free from acid, it retains its original color. If acids are present their action on the copper makes the color greenish or bluish. This test may also be made by dropping the oil on a sheet of copper or brass. Here it should be left for a week, when at the end of that time if acid is present, a greenish discoloration will be seen on the metal. Almost any of the chemical test for acid as with colored solutions and litmus paper will indicate the occurrence of acid. Litmus paper turns pink in the presence of acid. In its absence a blue color will be apparent.

To compare the lubricating values of several oils a few drops must be placed on a smooth, slightly inclined metal or glass sheet. The better and the greasier the oil the farther will a drop of it travel in any given time you determine upon.

Evils of Exhausting in Closed Shop.—With the coming of cold weather adjustments to motors are often made in the garage or testing shop proper, instead of outside, as is the case when weather conditions are mild. Many of the garages are insufficiently heated, and of course all doors and windows are kept closed in order to retain what heat there is present. When such is the case, care must be taken that the motors be run very little unless the windows and doors are opened to provide for ventilation. The exhaust gas is very poisonous and cases are known where workmen have narrowly escaped asphyxiation, when running motors continuously in the shop and exhausting directly into the room. If it is necessary to run a motor continuously and conditions are such that windows or doors cannot be opened for ventilation, it will be found desirable to lead the exhaust gas from the room by attaching a piece of heavy rubber hose from the discharge pipe of the muffler to a window, which need be open but a trifle, to allow the end of the rubber hose to hang out into the air. Such a simple precaution will save many a severe sick headache or something more serious. Where the hose goes on the exhaust pipe it must be lined with asbestos, to prevent the heat of the pipe decomposing or burning the hose. Owing to the free flow provided for the gas, the hose will not become unduly heated at other parts.

The exhaust gases from a gasoline engine are composed of nitrogen, a little free oxygen, hydrocarbon, hydrogen, carbon monoxide and carbon dioxide, the last two being considered dangerous. The presence of carbon dioxide as a product of combustion of the gasoline was recognized as an objection from the beginning of the use of these machines, but attention was called to the fact that the amount produced was relatively small compared to other sources of this gas, and it was not likely to be made in dangerous quantities. The effect of carbon dioxide, except in relatively large percentages, is confined to reducing the oxygen content of the air that is breathed. The presence of carbon monoxide in the exhaust gases

in injurious quantities was less apparent, but it appears from what is now known that this is the limiting factor in the use of engines exhausting into poorly ventilated places. The presence of carbon monoxide in the air in relatively small quantities has been shown to have a marked effect upon the blood, producing sickness, and if inhaled in sufficient quantity, death. After careful inquiry, the best that can be stated at this time is that without injury to health, no more than 0.1% of carbon monoxide can be breathed and that for a short and infrequent intervals. It is probable that one-half of this percentage could be allowed for a considerable period of time without noticeable effect. The per cent. of carbon monoxide in the garage air depends upon the amount made by the engines running and on the quantity of air with which it is mixed. It will be necessary to provide ventilation for the worst combination of gases which such engines can make under unskillful handling, or else to become informed as to the actual amount of carbon monoxide produced and provide air accordingly.

It is not sufficient to consider the average amount produced as distributed over the whole time of running such a machine. The total quantity of gasoline burned in any one day may have produced but a small quantity of carbon monoxide, but if this has been confined to a relatively short period during bad carburetor adjustment, and in some poorly ventilated space, the momentary percentage may be very high and the consequence may be fatal. It is evident that to be entirely safe the ventilation must be sufficient to keep the percentage of carbon monoxide below the assigned limit when the engine is producing the maximum quantity possible. If the maximum quantity is provided for by proper ventilation, the chance of injury to health may be considered to be remote. Certain peculiarities of gasoline engines cause the percentage of carbon monoxide generated to vary between rather wide limits, but the maximum is fairly constant. No other constituent of the exhaust gases varies so much or so rapidly with slight changes of adjustment as does the carbon monoxide. Conveying the exhaust gas to the outer air is the simplest and most positive remedy for disposal of this deadly gas.

Instructions for Repairing Storage Battery.—In repairing a

Willard storage battery a definite routine must be followed in tearing down and building up same in order that it will be in the best condition when re-assembled. These steps are as follows:

First: Remove all vent plugs and washers.

Second: Centerpunch both top connectors in each cell which is to be repaired; then drill ¾-inch into top connector, with a ⅝-inch diameter drill. Now pull off top connector with pair of pliers.

Third: Apply gas flame or blowtorch flame to the top of the battery long enough to soften the sealing compound under the top cover. Now, with heated putty knife, plow out the sealing compound around the edge of top cover.

Fourth: Insert a putty knife, or any other thin, broad pointed tool, heated in flame, along underside of top cover, separating it from the sealing compound. Then with putty knife, pry the top cover up the sides and off of the terminal posts.

Fifth: Then, with heated putty knife, remove all sealing compound from inner cover.

Sixth: Now play the flame onto the inner cover until it becomes soft and pliable; then take hold of both terminal posts of one cell, and remove the elements from the jar, slowly; then lift the inner cover from the terminal posts.

Seventh: Now separate positive and negative elements, by pulling them apart sideways. Destroy old separators.

Eighth: To remove a leaky jar, first empty the electrolyte from the jar, and then play the flame on the inside of the jar until the compound surrounding it is soft and plastic; then with the aid of two pairs of pliers, remove it from the crate, slowly, lifting evenly.

Ninth: To put in a new jar, in place of the leaky one, heat it thoroughly, in a pail of hot water, and force in gently.

Tenth: In re-assembling the battery, first assemble the positive and negative elements, pushing them together sideways; then turn them on the side and with both hold downs in place, insert new separators, being very careful to have the grooved side of the separators next to each side of each positive plate. Also be careful to have the separators extend beyond the plates on each side, so there will be no chance of the plates short-circuiting. Now press all separators up against hold downs.

Eleventh: Heat up inner cover with flame; then place same on terminal posts; then take hold of both terminal posts and slowly lower the elements into the jar

Twelfth: Now, with expansion chamber in place on the inner cover, pour the melted sealing compound on to the inner cover,

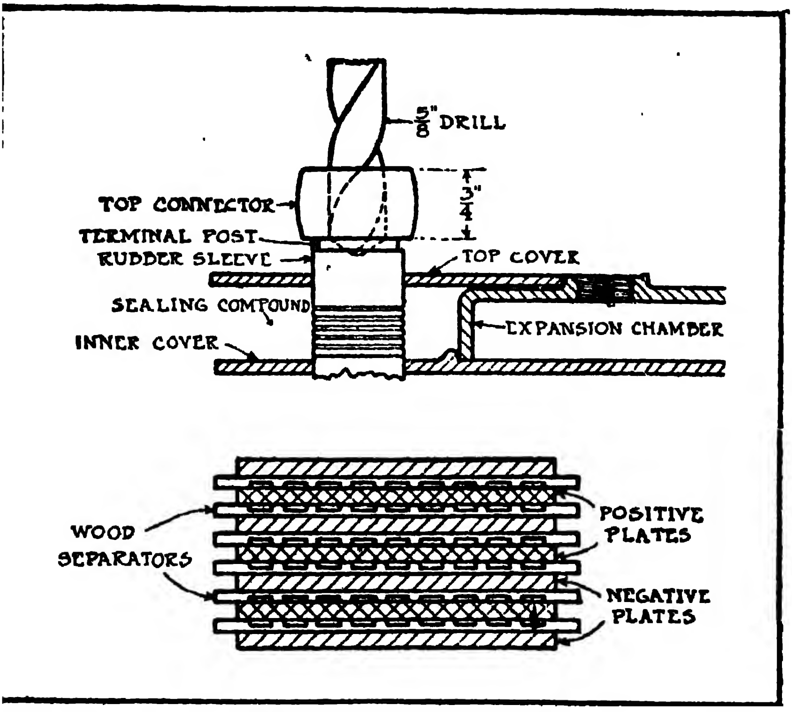


Fig. 464.—Diagram Showing Construction of Points to be Reached in Rebuilding or Tearing Down Willard Storage Battery.

until it reaches the level of the hole in the top of the expansion chamber,—*i.e.* so that when the top cover is replaced, it will squeeze the sealing compound off the top of the expansion chambers.

Thirteenth: Now soften top cover with flame and replace on terminal posts until it rests on top of expansion chamber; then place a weight on top cover until sealing compound cools.

Fourteenth: Now, pour sealing compound around the edge of the top cover, until it reaches the top of top cover; then when the sealing compound has cooled, take a putty knife and scoop extra sealing compound off of top cover, making a smooth surface over all the top of the battery.

Fifteenth: In burning the top connector to terminal post, proceed as follows: Scrape the hole of the top connector until the surface is bright and clean; scrape terminal post until top and edge are bright and clean. Now, scrape a piece of lead—preferably a small bar—bright and clean; then apply hydrogen gas flame, mixed with air under pressure, to the top connector and terminal post assembled, at the same time heating lead bar. When top connector and terminal post begin to melt, apply lead bar directly on same, melting it, thus making a firm burned connection. Then fill rest of hole-space with melted lead and smooth off even with top of top connector.

Care of Grinding Wheels.—Chattering and waviness in appearance of the part finished is usually caused either by the wheel spindle being loose in its bearings, the grinding wheel being out of true or out of balance, or particles of the material being ground having become embedded in the wheel. A loose spindle should, of course, have its bearings adjusted. In a great majority of cases, however, the cause of imperfect work is due to the wheel getting out of shape. It is important that its face should be perfectly parallel with the travel of the carriage, and in order to produce a result of this kind a diamond tool must be used, as near to the headstock or footstock center as is practicable, especially on work of small diameter. Where the work is not so small, say 2 inches in diameter, the truing device can be clamped at the most convenient point, and in either case it should be carefully seen to that the stud holding the diamond and the arm supporting same, are solid against the work. If the truing device is not rigid the face of the wheel will not be dressed perfectly true.

It will be observed that the stud in which the diamond is mounted can be revolved in its holder and it is important that the point presented to the wheel should be sharp; for instance, if the diamond should become worn and flattened, it should be turned

and thus present a new point to the wheel. Keeping the wheel true is important for the operator to observe, particularly so when he comes to make a final finish. The wheel should be traversed by the diamond at a uniform speed, rather slowly in order to give it time to cut away the particles. If it is desired to do rapid cutting, it will be found proper to pass the wheel by the diamond more rapidly thus making a rougher face on the wheel.

The number of times that the face of a grinding wheel has to be trued depends entirely on the character of the work being finished and the kind of wheel used. There are some wheels that wear away rapidly enough so that little truing is necessary. There are also cases where a harder wheel is desirable and a hard wheel necessarily requires more truing than a soft one. Where pieces are rather large and considerable stock has to be removed, it may be necessary to true the wheel each time a piece receives its finishing cut. Where the stock to be removed is not more than $\frac{1}{64}$-inch diameter it is advisable to finish in one operation, but when there is as much as $\frac{1}{32}$-inch diameter to be removed it is good practice to grind it in two operations. As stated above, it is desirable generally to present a sharp point of the diamond to the wheel in truing, but there are times when the smooth surface is preferable, particularly when it comes to producing a very fine finish; the flat surface of the diamond will tend somewhat to glaze the wheel and thus produce a better finish. A coarse wheel properly trued will produce a good finish.

The amount of wear the wheel is subjected tc depends upon the operator in many cases. Never bring an emery, corborundum or other abrasive wheel suddenly against the work or the work abruptly to the wheel. The feed should be gradual, so that the sparking will start almost imperceptibly. Grinding is not intended to be a roughing process but is a method of finishing in most cases so careful manipulation of the feed control is required to prevent the wheel from "digging" in.

Speed for Wheels.—The table below designates number of revolutions per minute for specified diameters of wheels, to cause them to run at the respective periphery rates of 4,000, 5,000 and 6,000 feet per minute.

SPEEDS FOR EMERY WHEELS.

Diameter Wheel	Revolutions per Minute for Surface Speed of 4,000 Feet.	Revolutions per Minute per Surface Speed of 5,000 Feet.	Revolutions per Minute per Surface Speed of 6,000 Feet.
Inch			
1	15,286	19,099	22,918
2	7,639	9,549	11,459
3	5,093	6,366	7,639
4	3,820	4,775	5,730
5	3,056	3,820	4,584
6	2,546	3,183	3,820
7	2,183	2,728	3,274
8	1,910	2,387	2,865
10	1,528	1,910	2,292
12	1,273	1,592	1,910
14	1,091	1,364	1,637
16	955	1,194	1,432
18	849	1,061	1,273
20	764	955	1,146
22	694	868	1,042
24	637	796	955
30	509	637	764
36	424	531	637

The medium of 5,000 feet is usually employed in ordinary work, but in specific cases it is sometimes desirable to run them at a lower or higher rate according to requirements. We recommend a number of revolutions equivalent to a surface speed of 5,500 feet. This does not indicate that they cannot be run at a higher or lower speed, but that it is a good average speed to produce good results. To allow an ample margin of safety it is recommended that wheels should not be run at a surface speed exceeding 6,000 feet. Every shop should have a speed indicator in order that the speed of its grinding machinery may be known.

Grading of Landis Grinding Wheels.

NUMBERS

The grains are numbered according to the number of meshes per lineal inch of the sieve through which they have passed. For example, No. 30 is a grain that will pass through a sieve having thirty meshes to the inch, but will not pass through a sieve having

thirty-six meshes. The fineness, or number, of the emery or corundum used in making a wheel determines the "number" of the wheel.

The grains (and similarly the wheels) are numbered as follows: 10, 12, 16, 20, 24, 30, 36, 46, 54, 60, 70, 80, 90, 100, 120, 150. In his list the lower numbers indicate the coarser grains, the higher numbers, the finer ones.

When ordering wheels, be sure to specify diameter, shape, thickness, size of center holes, the grade and grain or description of material to be ground and speed proposed to run the wheels. If possible, give shape number.

For grinding hardened steel and cast-iron, wheels made by what is known as the silicate process give very good results, but the vitrified wheel in our experience is the better for general use.

A soft wheel is less apt to change the temperature of the work or become glazed.

A wheel is most efficient when just soft enough not to glaze and hard enough not to wear away rapidly.

Use a fine grained wheel for finish, a coarse wheel to remove stock, For general grinding a 24 combination grain wheel gives excellent results.

A good practice is to have several grades of wheels on hand best adapted for your different classes of work.

Always keep a spare wheel or two on hand for emergencies.

Vitrified Process		Silicate Process	Vitrified Process		Silicate Process	Vitrified Process		Silicate Process
Very Soft	E	¾	Soft	K	2¼	Hard	Q	5
	F	1		L	2½		R	5½
	G	1¼	Medium	M	3		S	6
	H	1½		N	3½		T	6½
Soft	I	1¾		O	4	Very Hard	U	7
	J	2		P	4½			

CHAPTER XII

USEFUL INFORMATION FOR AUTO REPAIRMEN.

Anti-Freezing Cooling Solutions—Substances Usually Combined with Water—Advantages of Different Solutions—Electrolytic Action Not Desirable—The Best Mixture—Extinguishing Fires in Volatile Liquids—First Aid to the Injured—Schaefer Method of Artificial Respiration—The Repair Shop Medicine Chest—Remedy for Burns, Cuts and Abrasions—Wounds and Painful Injuries—Home-made Aseptic Gauze.

Anti-Freezing Cooling Mediums.—To lower the freezing point of water it is possible to add various substances and the proportions added determine the point at which the solution will congeal. Among the materials commonly used may be mentioned common salt, alcohol, glycerine and calcium chloride. The alkaline solutions produce a distinct electrical action wherever two dissimilar metals are used together in the cooling system, such as the brass tubing of a radiator and the solder used at the joints; the cast iron water jacket and the aluminum or brass plates used to close the core print holes; the aluminum pump casing and steel or bronze impeller, and at many other points which will vary with the design of the car and the materials of the components. The alcohol solutions evaporate very quickly, the glycerine solution affects the rubber hose, and the salt solutions leave an incrustation as the water evaporates. It is reasonable to expect electrolytic action when metals of different potential are used together in any alkaline solution, which are electrolytes of high value. Taking it all in all, the selection of the best solution involves a consideration of many facts and various requirements must be considered in the selection of that most suitable. Considering the qualities of such a compound it will be seen that no one will combine all the desirable

features, so in selecting the solutions the following should be kept in mind: To begin with, and it is a highly important consideration, the solution used should have no corrosive action, nor should its use prove deleterious on the metals or rubber used in the circulating system. It must be easily dissolved in or combined with water, must be reasonably cheap and not subject to rapid waste by evaporation, and should not be of such character that it will deposit sediment or foreign matter in the jackets, pipes or radiator water spaces. Its boiling point should be as high, if not higher than, that of water, and it should not congeal at temperatures ordinarily met with where it is used.

Substances Usually Combined with Water.—Alcohol is prepared by destructive distillation of various vegetable substances which contain starch or sugar, such as potatoes, beets and numerous grains and fruits. Any starchy material will serve for the production of alcohol and the real question is one of cost, which varies with the locality in which the manufacture is carried on. It mixes readily with water, and does not congeal at any known temperature, though its boiling point is about 175 degrees Fahrenheit, and above this point evaporation is rapid. It is a very volatile liquid and will evaporate at very moderate temperatures. The alcohol generally used is denatured by the addition of a substance which renders it unfit for drinking purposes and because of the recent removal of the government tax it may be obtained for about 60 cents a gallon.

Glycerine is obtained as a by-product in the saponification of fats in soap and candle making, and is an oily substance which will vary in color from reddish brown when crude to a colorless liquid when pure. Crude glycerine sometimes contains free acids in small quantities though it may be purified and the color removed when it is to be used for certain purposes. This substance has a much higher boiling point than water, ebullition taking place at a temperature of 554 degrees Fahrenheit. Glycerine when pure is a sweet, colorless liquid and is mixable with water and alcohol in any proportion. It is most largely used in the manufacture of nitroglycerine, though utilized to some extent in pharmacy, soapmaking, filling instruments which require a liquid seal and which

are exposed to low temperatures, and sweetening wine. It can be obtained in single gallon lots at a cost about $1.50.

Calcium chloride is a by-product of the Weldon process of obtaining chlorine which is to be incorporated into bleaching powder, from manganese ore and hydrochloric acid. It is a salt and is produced in the form of crystals, the crude material being yellowish white in color, though after purification it is clear white. It may be obtained directly from marble or chalk by dissolving these materials in hydrochloric acid. It is comparatively cheap and may be obtained in 10 pound sheet iron drums at nine cents per pound. Chemically pure its cost will vary from 30 to 60 cents per pound. It is very soluble in water, and while it is in solution it will lower the freezing point. It may contain free acid in the crude form, though this may be neutralized by the addition of a little slaked lime. Water will be evaporated rapidly at temperatures in excess of 185 degrees and salt will remain in the form of crystals. While calcium chloride solutions have been very popular they are not so well thought of at the present time because of a certain electrical action which is set up when the water circulation system is composed of dissimilar metals, as is commonly the case in motor car construction and corrosion at the points of juncture is unavoidable. As hydrochloric acid is used when this salt is obtained, there may be some free acid in combination with the cruder grades, and corrosive action will be noted. The corrosive action of chemically pure salt is very slight, though electrical action will be noted if dissimilar metals are employed, regardless of the purity of the salt in the solution.

Advantages of Different Solutions.—The substances previously discussed all have advantages, some as relates to first cost, others to freedom from trouble. Alcohol is without doubt the best material to use from the viewpoint of action on metal or rubber, as it does not form deposits of foreign matter, will not freeze at known temperatures, and has no electrical effect. It is extremely volatile, however, and because of its low boiling point will evaporate at temperatures much less than that of the boiling point of water, and the solution in the water circulation system of the modern motor car often heated to this point, especially when the

natural system of water circulation is employed. Combinations of water, alcohol and glycerine have been tried, and have given excellent results. The addition of the glycerine to a water-alcohol solution reduces liability of evaporation to a large extent and increases the boiling point. Glycerine and water solutions were formerly considered favorably, but of late have been abandoned because of certain strong disadvantages. Crude glycerine often contains free acid, and in many cases, if no free acid is found, it may break down when exposed to heat, and liberate fatty acids, which are found combined with other elements in all fats and oils of animal or vegetable origin. While this acid may not attack metals to any appreciable extent, still its presence in the cooling system is not desirable. Glycerine, as is true of most oils, has a destructive effect on rubber hose and gaskets, and should not be used in large proportions on any car where much of the piping system is of rubber hose. Glycerine is expensive and is liable to decompose under the influence of heat, and as the proportions used with water are larger than is necessary with other substances, these solutions are being replaced with alcohol, water and glycerine compounds, which are most satisfactory in ordinary practice.

Positive Proof of Electrical Action.—To demonstrate that with saline solutions a certain amount of electrical action was unavoidable, the writer made a series of tests in which a number of pairs of dissimilar metals were placed in calcium chloride solution and a low-reading voltmeter interposed in the circuit showed voltage ranging from one-fifth to one-half volt, depending upon the metals used, the strength of the solution and the temperature. The electrical action in every case was greater as the temperature was increased. Extreme care was taken in making these tests, and the results obtained were carefully checked by another series of tests with the same metals and fresh solutions. The solution used was the weakest of the calcium chloride and water combinations, and was made of two pounds of salt to a gallon of liquid. This solution has a freezing point of 18 degrees F., only a few degrees lower than plain water. With zinc and copper the current indication was two-fifths of a volt, just half as much energy as obtained with sal-ammoniac, a recognized electrolyte, in previous test. The tempera-

ture was about 68 degrees Fahrenheit. Copper and cast iron showed more energy than when the same elements were immersed in standard electrolyte, namely, three-tenths of a volt. Copper and solder showed the same as when sal-ammoniac was used, the indication being one-fifth volt. When aluminum and cast iron were tested the indication was less than one-tenth volt. Aluminum and brass produced one-fifth volt, brass and solder one-tenth volt and brass and cast iron one-tenth volt. This electrolyte is the weakest of the calcium chloride solutions which have been advised by men who know, for use in the circulation system. Its suitability for the purpose is left to the reader's judgment.

The results with the stronger solution were about the same, the only difference noted being that the needle moved over further with each stronger solution, though it settled to about the same reading as with the weaker solution for the same elements. All the elements were tested in four different mixtures and results carefully noted. To test the effect of increased temperature on current production, four ounces of the strong solution, that of five pounds calcium chloride to the gallon of water, was heated to 180 degrees Fahrenheit, a temperature slightly less than its boiling point, and the zinc and copper elements placed in the jar and a reading taken. While the reading at 70 degrees Fahrenheit was two-fifths volt, at the higher temperature the indication of the needle was three-fifths volt, almost as much as obtained with the regular sal-ammoniac solution at normal temperatures.

Electrolytic Action Not Desirable.—Where there is electrical action there is also corrosion and deterioration of the metal which acts as the negative element. While it is true that the current produced between the metals falls off in pressure because of polarization of the positive element, it must be considered that the constant circulation of the solution through the jacket and piping must to a certain extent act as a depolarizer because of agitation of the liquid, which has a tendency to keep the surface of the positive element free from gas bubbles. It is reasonable to assume that there will be a continued electrical action all the time that the solution is in a cooling system, though at times this may be very slight. To be sure that the action was caused by the calcium chloride alone

and not acid in solution the various solutions were carefully tested with litmus paper for acid without detecting the minutest trace. Then for the purpose of testing the litmus paper a single drop of hydrochloric acid placed in the solution turned the blue litmus to a light pink, proving conclusively that the test paper was of proper strength. Then consider that all the time the engine is in operation the temperature is nearly to the boiling point of the solutions, in some cases more, and it will be seen that the degree of electrical activity is considerably increased.

The cellular cooler is composed of innumerable soldered joints and at every one of these there will be a certain amount of electrical action, which in the aggregate will amount to a considerable current. At various other points of the cooling system, wherever there is two unlike metals in combination, we have other small currents, which decompose their quota of metal and assist in filling the system with sediment and foreign matter, not to mention the salt crystals which will be formed as the solution evaporates. The writer does not claim that the test showed absolute results, but they demonstrated that without doubt electrical action does exist when solutions of calcium chloride or any other salt are used to prevent freezing.

The Best Mixture.—Plain water and alcohol solutions would be the best were it not for the ease with which such compounds boil and the rapidity with which they evaporate. We have seen that the objections advanced against calcium chloride solution have ample foundation and that such compounds are not suitable for use, the chief advantage, that of cheapness, havi g been eliminated by the reduction in the price of denatured alcohol. The addition of a little glycerine to an alcohol and water solution reduces liability of evaporation, and when used in such quantities it has no injurious effect to speak of on rubber hose. The tables show the combinations and their freezing points and the proper proportions of the mixtures used must, of course, be governed by conditions of locality, but it is better to be safe than sorry, and make the solutions strong enough for the extremes that may be expected. The writer has used both alcohol and water, and glycerine, alcohol and water solutions, with good results, though considerable trouble

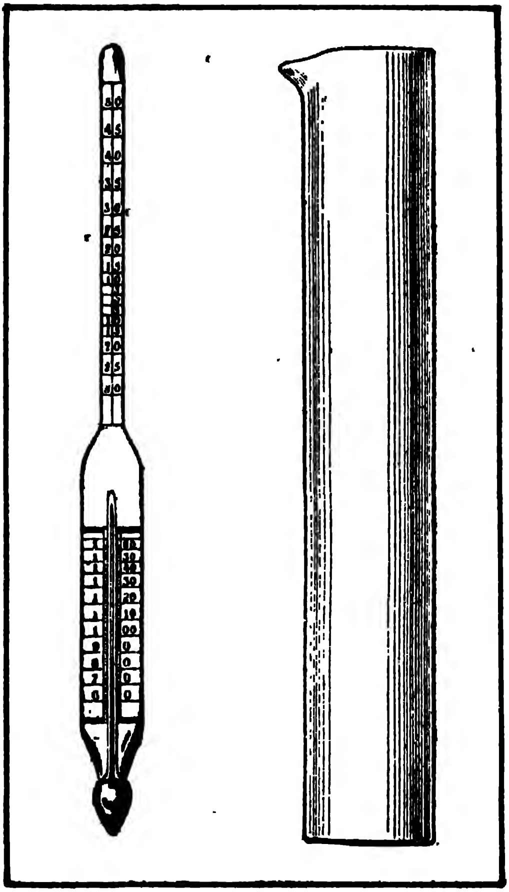


Fig. 465.—Special Testing Hydrometer for Determining Density of Alcohol-Water Cooling Solutions, Giving Freezing Points.

has already been experienced when saline solutions were employed.

Oils of various kinds have been recommended, these being of the character often used in lubricating ice-making machinery, and made especially to withstand low temperatures. Such oils will not absorb heat as well as water and should be used only where exceptionally good methods of cooling are provided, such as a large radiator, all metal piping and positive pump. This oil will attack rubber hose, however, and it would seem, all things considered, alcohol solutions are preferable to all others. The following tabulations give the relative values of solutions commonly employed:

CALCIUM CHLORIDE SOLUTIONS

2 pounds salt, 1 gallon water	**Freezing point, 18° F.**
3 pounds salt, 1 gallon water	**Freezing point, 1.5° F.**
4 pounds salt, 1 gallon water	**Freezing point, −17° F.**
5 pounds salt, 1 gallon water	**Freezing point, −39° F.**

WATER AND ALCOHOL SOLUTIONS

Water 95%, Alcohol 5%	Freezing point, 25° F.
Water 85%, Alcohol 15%	Freezing point, 11° F.
Water 80%, Alcohol 20%	Freezing point, 5° F.
Water 70%, Alcohol 30%	Freezing point, −5° F.
Water 65%, Alcohol 35%	Freezing point, −16° F.

WATER, ALCOHOL AND GLYCERINE SOLUTIONS

Water 85%, Alcohol—Glycerine 15%	Freezing point, 20° F.
Water 75%, Alcohol—Glycerine 25%	Freezing point, 8° F.
Water 70%, Alcohol—Glycerine 30%	Freezing point, −5° F.
Water 60%, Alcohol—Glycerine 40%	Freezing point, −23° F.

Alcohol and Glycerine—equal proportions.

EXTRACTS FROM A PAPER READ BY EDW. H. BARRIER BEFORE THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

Extinguishing Fires in Volatile Liquids.—The extinguishing of fires in oils, gasoline and in most of the volatile liquids has always been a difficult problem and where fires of this kind occur the results are frequently very disastrous. Our most common extinguishing agent, water, works rather unsatisfactorily upon the majority of such fires, but it is still the only one available where heroic measures are required. Comparatively recently, however, there have been two or three other materials introduced for use as extinguishers which have shown some promise for dealing with these fires, and it is the writer's purpose to discuss these materials and the conditions under which they prove the most efficient. Not all fires in volatile liquids are difficult to handle with water. When the liquid is miscible with water this extinguishing agent can be successfully used. Examples of this kind are denatured alcohol, wood alcohol, grain alcohol, acetone, etc. Where the liquid is not miscible with water little or no effect is produced except to wash the burning liquid out of the building where it may be completely consumed, or, if the quantity of oil is small, possibly to extinguish the fire by the brute cooling effect of a large quantity of water sprayed upon the fire. Soda and acid extinguishers are somewhat

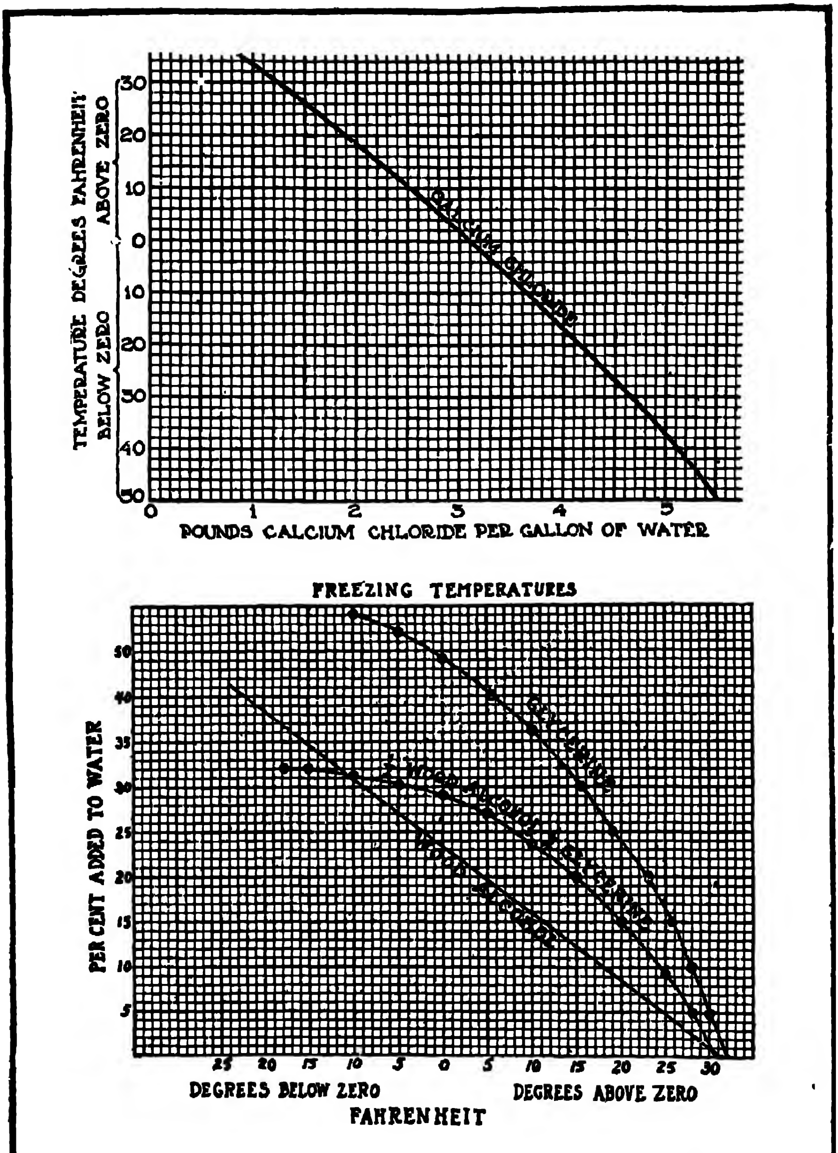


Fig. 466.—Charts Showing Freezing Points of Various Mixtures of Calcium Chloride, Alcohol, etc., and Water.

more effective than pure water, but even they fail under most conditions. The various grenades containing salt solutions which were formerly extensively exploited are of course practically worthless. The only principles that can be made use of in extinguishing fires in volatile oils are (a) to form a blanket either of gas or of solid material over the burning liquid which will exclude the oxygen of the air or (b) to dilute the burning liquid with a non-inflammable extinguishing agent which is miscible with it.

Sawdust and Bicarbonate of Soda.—To the blanketing type of extinguishers belongs sawdust. Paradoxical as it may seem, ordinary sawdust is an excellent extinguishing agent for certain volatile liquids, especially those of a viscous nature. A considerable number of experiments were conducted in the fall of 1912 by the inspection department of the Associated Factory Mutual Fire Insurance Companies, in the extinguishing of fires in lacquer and gasoline in tanks with sawdust, and the results were surprisingly satisfactory. The liquids were placed in three tanks 30 inches long, 12 inches wide and 16 inches deep; 48 inches long, 14 inches wide and 16 inches deep; and 60 inches long, 30 inches wide and 16 inches deep. The sawdust was applied with a long-handled, light but substantially built snow shovel having a blade of considerable area. In every case the fires were extinguished readily, especially in the two smaller tanks which were about as large as any ordinarily employed for lacquer in manufacturing establishments. The efficiency of the sawdust is undoubtedly due to its blanketing action in floating for a time upon the surface of the liquid and excluding the oxygen of the air. Its efficiency is greater on viscous liquids than thin liquids, since it floats more readily on the former than on the latter. The sawdust itself is not easily ignited, and when it does become ignited it burns without flame. The burning embers have not a sufficiently high temperature to reignite the liquid. The character of the sawdust, whether from soft wood or hard wood, appears to be of little or no importance, and the amount of moisture contained in it is apparently not a factor, so that the drying out of sawdust when kept in manufacturing establishments for a time would not affect the efficiency. It was found that the admixture of sodium bicarbonate greatly increased the efficiency

of the sawdust as shown both by the shortened time and the decreased amount of material necessary to extinguish the fires. A further advantage of the addition of bicarbonate of soda is that it decreased the possible danger resulting from the presence of sawdust in manufacturing plants since it would be difficult if not impossible to ignite the mixture by a carelessly thrown match or any other source of ignition. Although the efficiency of the sawdust is greatest on viscous liquids such as lacquers, heavy oils, japan, waxes; etc., in the test referred to, fires were extinguished in gasoline contained in the smallest tank and also when spread upon the ground. In larger tanks the sawdust or bicarbonate mixture does not work so well since the sawdust sinks before the whole surface can be covered, whereupon the exposed liquid reignites.

Carbon Tetrachloride.—In recent years carbon tetrachloride has received considerable attention as a fire extinguishing agent. This is due largely to the activity of certain manufacturers of fire extinguishers which use liquids, the basis of which is carbon tetrachloride. This substance is a water white liquid and possesses when pure a rather agreeable odor somewhat similar to chloroform. A considerable proportion of the commercial article upon the market, however, contains sulphur impurities which impart a disagreeable odor to the liquid. The substance is quite heavy, its specific gravity being 1.632 at 32 degrees Fahr. It is non-inflammable, non-explosive, and is readily miscible with oils, waxes, japan etc. When mixed with inflammable liquids it renders them non-inflammable provided a sufficient quantity is added. Its vapor is heavy, the specific gravity being about five and one-half times that of air, consequently it settles very rapidly. As an extinguishing agent it operates by both the principles mentioned, namely, it dilutes the inflammable liquid rendering it non-flammable, or at least less inflammable, and it forms a blanket of gas or vapor over the burning liquid which excludes the oxygen of the air.

Although this exposition is confined to a discussion of extinguishing fires in oils and volatile liquids, it may not be out of place to mention that the claims made by certain manufacturers producing extinguishers which use liquids, the basis of which is carbon tetrachloride, are grossly exaggerated. These preparations, none

of which is more efficient than carbon tetrachloride, are not the equivalent of the ordinary water extinguishers for general use on such materials as cotton, wood, paper, oily waste, etc. On volatile liquids, oils, etc., carbon tetrachloride has, however, shown very satisfactory results under some conditions, but the readiness with which a fire can be extinguished with it depends to a considerable extent upon the skill of the operator and the length of time that the liquid has been burning is an important factor, and in such cases where the sides of the tank become heated the only way in which the fire can be extinguished is to squirt the liquid forcibly at the sides. If the carbon tetrachloride is squirted directly into the liquid it is much more difficult, if not impossible to extinguish the fire. The height of the liquid in the tank is also a very important factor. Where the liquid is low the sides form a pocket which retains the vapor and aids considerably in smothering the blaze. When the tank is nearly full, however, this condition does not exist, and it is then very difficult, if not impossible, to extinguish a fire in a highly volatile liquid such as gasoline; only the most skilled operators are successful in these cases.

The size of the tank or the extent of the fire upon the floor is, as would be expected, of considerable importance. In tanks larger than about 28 inches by 12 inches more than one extinguisher and operator working at a time are necessary to extinguish a fire in such materials as gasoline. In one test where a tank 60 inches by 30 inches was used no less than seven operators were necessary, and even then it was only with the greatest difficulty that the fire was put out. All of the above remarks apply to tetrachloride in the ordinary one quart extinguisher as generally sold. It is probable that a large extinguisher which could throw a large stream would prove more efficient, but on account of the great weight of carbon tetrachloride such an extinguisher would have to be specially designed to make it readily portable by mounting on a truck or some similar means. Expelling the liquid by means of a hand-pumping arrangement would probably be unsatisfactory, and it would therefore be necessary to force it out in some other way.

A few systems have recently been installed in which an elevated tank containing tetrachloride was connected with automatic sprink-

lers or perforated pipes located in hazardous rooms where volatile and inflammable liquids are in use. So far as is known none of these systems has as yet been called upon to extinguish a fire, but there appears to be no reason why such a system should not provide excellent protection in special cases. In such systems it would be necessary to consider the safety of the workmen and furnish ready means of escape, since carbon tetrachloride is an anesthetic and where thoroughly sprayed through the air as from an automatic sprinkler it would probably produce rapid results. The nature and effect of the fumes given off when carbon tetrachloride is thrown upon the fire is a subject which has received a great deal of discussion. When the liquid comes in contact with a fire the vapor is partly decomposed resulting in the evolution of a considerable quantity of black smoke which undoubtedly is divided carbon. Pungent gases are also produced which appear to be mostly hydrochloric acid with possibly a small amount of chlorine. Since carbon tetrachloride contains no hydrogen from which hydrochloric acid can be formed this substance must be produced by the action of chlorine on the gases arising from the burning material or upon the moisture of the air. The fumes of carbon tetrachloride although of a very pungent nature, do not produce any permanent injury under ordinary conditions where the operator can make his escape after he has inhaled all that he can stand, but they are a distinct handicap in fighting a fire and are one of the objectionable features to carbon tetrachloride as a general fire extinguishing agent. In large rooms or where a small quantity of carbon tetrachloride is sufficient to extinguish a fire the gases are of course less objectionable.

Frothy Mixtures.—Another method of extinguishing fires in oils and volatile liquids which has recently been proposed and experimented with is that of using frothy mixtures. The idea seems to be a very promising one, and the tests which have been thus far reported indicate very satisfactory results. The idea was originated and has been developed in Germany. So far as is known no experiments along this line have been conducted in this country. The process consists essentially in causing two liquids to mix in a tank where foam is produced. The tank is made airtight and suf-

ficiently strong to permit of the foam being forced out by carbon dioxide under pressure and the foam is conveyed to the fire by means of a line of hose. The exact nature of the liquids has not been disclosed, but one of them probably consists of a sodium carbonate solution containing froth-forming ingredients such as glue or casein and the other an alum solution. The two on coming together generate carbon dioxide, which produces froth. This froth is reported to be quite stiff and to shrink in volume but a comparatively small amount even after a period of half an hour. A number of tests were conducted in the winter of 1912 in Germany; some of them on a considerable scale. In one case as much as five tons of crude naphtha in a tank was involved, and in another an area of 1,300 square feet of burning tar was used. In all cases the results were reported satisfactory, the fires being extinguished in a short time.

The frothy mixture undoubtedly owes its efficiency to its blanketing action in settling upon the surface of the burning liquid, thus excluding the oxygen of the air, and to the fact that the bubbles of liquid contain carbon dioxide which, upon bursting, produce an atmosphere in which combustion cannot take place. According to the latest report the matter is still in an experimental stage, various details regarding the form of apparatus, most efficient pressure and design of nozzles being under consideration; but from what has already been done it would appear that the idea is a very promising one.

First Aid to Injured.—While automobile repairing is not classed as a precarious occupation, accidents are frequent in the shop or on the road and a knowledge of first aid principles may often avert more serious consequences and do much to alleviate the pain of the injured person pending the arrival of a competent physician. The following information may be studied to advantage by all interested in mechanical work and by automobile operators as well.

Shock: Shock is a sudden depression of the vital powers arising from an injury or a profound emotion acting on the nerve centers and inducing exhaustion. The symptoms are subnormal temperature and irregular, weak and rapid pulse; a cold, clammy, pale, and

profusely perspiring skin; irregular breathing; the person affected usually remains conscious and will answer when spoken to, but is stupid and indifferent and lies with partly closed lips. Always be sure that there is no concealed hemorrhage.

Treatment: Lower the head, wrap the patient in hot blankets, and surround him with lamps or other heat giving objects. Give an ordinary stimulant, as black coffee, to be sipped as hot as it can be borne; half teaspoonful doses of aromatic spirits of ammonia may be given every 20 or 30 minutes. Small doses of whisky or brandy may be given, provided there is no hemorrhage. One or two teaspoonful every 15 or 20 minutes will help to tide the patient over until the doctor comes. Inhalation of oxygen is often of much service; artificial respiration may be necessary in some cases. Hot applications over the heart and spine should be used if practical. Always hurry up the doctor.

Fractures: A fracture is a break in a bone caused by a direct or indirect violence. Fractures are the most important class of injuries with which we have to deal, not only because they render the victim a cripple for the time being, but because the further usefulness of the limb depends upon the recognition of the trouble and its proper immediate treatment. Frequently ignorance or carelessness in handling a fracture in the beginning renders the sufferer an invalid or cripple throughout his life.

Treatment: In examining the fracture great gentleness in handling the part should be exercised. The limb should be handled as little as possible. If the nature of an injury is in doubt, it should be treated as a fracture until the doctor arrives. Never allow a person suffering from a broken limb to be moved until the part is properly supported by splints. To treat a fracture, draw the fractured limb into a natural position and hold it there by the application of splints.

Dislocations: A dislocation is a complete separation or displacement of the surfaces of a joint, caused usually by direct violence, but may sometimes be produced by indirect violence or sudden muscular contraction. The symptoms are: Pain, swelling, discoloration, rigidity; the natural position of the limb is changed; the length is altered.

Treatment: Restore the bone to normal position and hold it in place. To properly reduce the dislocation, some surgical skill and knowledge of the anatomy of joints are required. First-aid men should never try to reduce any dislocations except those of the jaw and fingers.

Sprains: A sprain is a twisting or wrenching of a joint, producing a tearing of the ligaments and sometimes of the surrounding soft parts. It is followed by severe pain and marked swelling and discoloration. Sprains are important injuries and should be properly treated immediately, as sometimes permanent disability may follow failure to give them proper care. They are very often more serious than a fracture.

Treatment: Let the injured person rest; elevate the injured part and fix it in place either with splints or by wrapping the joint tightly with a roller bandage or with adhesive plaster. Give hot or cold applications by placing the injured part in hot or cold water or by the application of towels wrung out of ice water or hot water.

Strains:. A strain is the wrenching or tearing of a muscle or tendon and is usually caused by violent exertion or sudden unexpected movements. A strain generally occurs in the muscles or tendons of the arms or legs. The symptom is sudden, sharp excruciating pain.

Treatment: Let the injured person rest; bandage the injured part tightly or apply adhesive plaster. It is sometimes necessary to prevent movement of the part by splinting.

Burns and Scalds: Burns are caused by exposure of the body to dry heat, such as the heat of fire or explosions of gas and powder, whereas scalds are produced by moist heat, as the heat of boiling water or steam. The danger from a burn depends upon its depth and extent, and also on the age and general condition of the person injured.

The symptoms in a first-degree burn are: Severe, burning pain, reddening of the skin, formation of blisters; in a second-degree burn destruction of the skin; in a third-degree burn, destruction of the skin and some of the tissue beneath. In severe burns shock is present.

Treatment: Carefully remove the clothing from the burned part, exclude the air as quickly as possible from burned surface with some clean covering and treat for shock.

The most generally used covering for burns is picric-acid gauze. This is ordinary sterile gauze which has been saturated with one-half to one percent. solution of picric acid. It has this advantage—it is clean and ready for use. Moisten the picric-acid gauze with clean water and put it over the burned surface. Over the gauze place a layer of absorbent cotton then apply a bandage to hold in place.

Carron oil, which is a mixture of equal parts of limewater and linseed oil, is often used, and is very good. It is applied as follows: Take a piece of sterilized gauze large enough to cover the burned surface; saturate the gauze with carron oil and cover the burn. Dress with absorbent cotton and cover with a bandage.

Vaseline, sweet oil, olive oil and balsam oil are all good dressings. If nothing better is at hand dissolve some bicarbonate of soda in sterilized water. Gauze wrung out of this and spread over the burn will give relief. Remember that severe burns are accompanied by shock, and always treat a burned patient for shock as well as for burns.

Schaefer Method of Artificial Respiration: Free the victim from electric current conductors or in case of drowning, roll on a barrel to expel water and instantly remove him to fresh air. Rapidly feel with the finger in his mouth and throat and remove any foreign body (tobacco, false teeth), then begin artificial respiration at once. Proceed as follows:

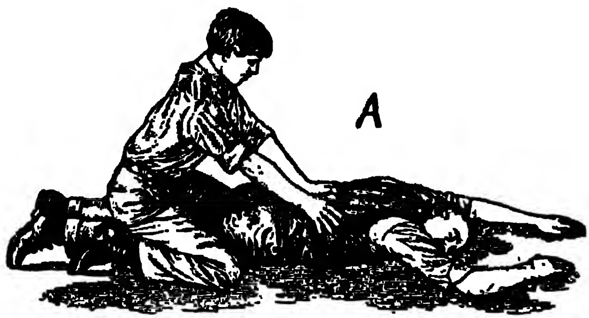
Lay the subject on his stomach with arms extended as straight forward as possible and with face to one side so that the nose and mouth are free for breathing. Let an assistant draw forward the subject's tongue.

Kneel straddling the subject's thighs and facing his head; rest the palms of your hands on the loins (on the muscles of the small of the back) with the fingers spread over the lowest ribs (Fig. 467 A).

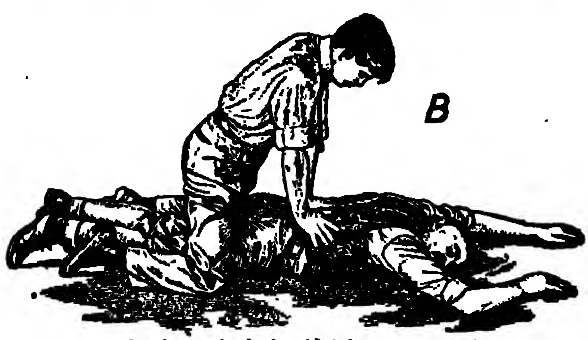
With arms held straight, fingers forward, slowly swing forward so that the weight of your body is gradually and without violence

brought to bear upon the subject (Fig. 467, B). This act should take two to three seconds. Then immediately swing backward so as to remove the pressure, returning to the position swing in Fig. 467, A. Repeat regularly 12 to 15 times per minute the swinging forward and backward, completing a respiration in four or five seconds.

As soon as this artificial respiration has been started and while it is being conducted an assistant should loosen any tight clothing about the subject's chest or waist. Continue the artificial respira-



Schaefer method of artificial respiration. Inspiration.



Schaefer method of artificial respiration. Expiration.

Fig. 467.—Illustrating Shaefer Method of Artificial Respiration.

tion without interruption until natural breathing is restored (if necessary two hours or longer) or until a physician arrives. If natural breathing stops after having been restored, use artificial respiration again. Some patients have been revived after several hours of hard work.

As soon as signs of life appear the lower limbs should be elevated and rubbed vigorously toward the heart. Hot applications should be used over the heart if practicable. If the patient gains consciousness and is able to swallow give hot coffee or half-teaspoonful doses of aromatic spirits of ammonia and treat as in shock. Do not put any liquid in the patient's mouth until he is fully conscious. Give the patient fresh air, but keep him warm.

Send for the nearest doctor and pulmotor as soon as the accident is discovered.

Automobile Repair Shop Medicine Chest.—The following extracts are from an article by Dr. W. R. Ingraham published in the Scientific American. The instructions are so plainly given that they can be followed to advantage by the repairman and machinist, and the various remedies and supplies mentioned may be advantageously included in the shop equipment because the various minor accidents that may happen in the shop may be treated by some shopmate or member of the clerical force trained for this duty, and men kept at work after minor wounds are dressed.

Remedy for Slight Burns.—Does the "Handy Man" ever burn himself? Of course. One of the best, most convenient remedies he can use is solution of picric acid in water. It is very satisfying and just a little gratifying to have the excessive pain of first degree burns instantly quieted. First degree burns are superficial, and the nerve endings, not being destroyed as in the deeper second and third degree burns, set up a howling remonstrance in the way of pain. Picric acid of a strength 1 to 200 (about one-third teaspoonful to one pint of water) or a saturated solution is used. It is antiseptic and will prevent suppuration. It is analgesic and "will make it feel good." It stains yellow, but the stain comes out in the wash. Keep a small vial handy. When you get a burn (if skin is not broken), sprinkle a little acid in a basin of water. Saturate a strip of gauze or cloth with this and bandage in place. In

a very little while (or as soon as the picric acid coagulates the albuminous exudate) the pain is quieted.

For Deep Burns.—Use picric acid as above for deeper burns (blisters and broken skin) but more carefully. Pour a little alcohol in the basin to be used. Roll it about so that the alcohol wets all the inside. Set it on fire and every germ in that pan dies instantly. Pour water that has been boiled from the teakettle into the pan, and add the picric acid. Bandage the burn with clean aseptic gauze and saturate it with solution. Blisters should be opened and contents expressed. Open them with a needle, the business end of which is sterilized by holding in the flame of a match. The soot will do no harm. For still deeper burns or burns of large area (third degree) much can be done by the above to alleviate suffering until a physician can be had, but send for him at once. The attending shock is serious.

For Small Cuts and Abrasions.—If the Handy Man cuts his finger or knocks the skin off his knuckle he should proceed as follows: 1. Cleanse the wound. Hydrogen peroxide is becoming a favorite antiseptic and with good reason. Besides being a germ killer it acts and cleanses mechanically. Its effervescence dislodges and carries away dirt and any foreign matter that might infect the wound. Try it on a splinter of decayed wood at which you have picked and fussed in an endeavor to extract. The hydrogen peroxide "boils" it right out. Therefore cleanse the cut by pouring on from a bottle a little of it, full strength. (A medicine dropper is convenient.) 2. Dust on a little aristol. Aristol is an iodine compound, having the useful antiseptic properties of iodoform, but lacks the disagreeable odor and irritating properties of the latter. With the exudate from the wound it forms a good artificial antiseptic scab. It may be purchased in small sifting top bottles. 3. Apply a protective dressing.

A bit of absorbent cotton pasted down over the wound with collodion forms a stiff protecting shield, which stays in place. It may be washed over with soap and water and will not require renewal for two or three days. For a contused finger nail, or cut near the end of a finger so liable to painful knocks it forms a stiff, comfortable thimble that is soft inside, looks better than a rag and

does not interfere with work. For smaller, more superficial wounds than the above a useful dressing, better than the questionable court plaster, or even adhesive tape, is collodion, to which has been added aristol or iodoform (50 grams to the ounce). A small glass rod, the ends of which have been made smoother by melting with a blowpipe in an alcohol flame, makes a convenient applicator for the collodion. Pass it through the cork and leave it in the bottle permanently

For Wounds and Painful Injuries.—In case of a deep wound the collodion dressing is not applicable and the soothing properties of a moist dressing are desired. Pour a measured quart of water into the basin to be used. Gauge the quantity with your eye. Throw out the water and sterilize the basin (as above) by pouring a little alcohol into the basin and rolling it about to wet all the inside. Set it on fire with a match and the basin is thoroughly sterilized. Pour a quart of water that has been boiled directly from the teakettle into the basin. One tablet of bichloride of mercury (as usually prepared) makes a 1 to 2000 solution when added to the quart of water. Sterilize another smaller basin by the method described above and pour a part of the solution into it for later use. Cleanse the wound as thoroughly as conditions permit.

Hydrogen peroxide of full strength or diluted with water is usually sufficient. If the wound is very dirty and much lacerated, as machinists' wounds are apt to be, the following method of cleaning is perhaps better:

Add to 1 quart warm water in which the wound is to be washed 2 teaspoonsful lysol. (This makes about 1 per cent. solution.) Lysol has an odor similar to carbolic acid, but is not so poisonous. It forms a soapy solution, hence its value as a cleansing agent. It numbs the parts and makes them less sensitive to pain. The part should now be thoroughly irrigated with the bichloride solution in the larger basin, being sure that all the lysol solution is removed from the wound.

Surgically clean gauze (sterilized, aseptic) is now bandaged over the wound and moistened with the clean bichloride solution saved in the smaller basin for this purpose. Bandage lightly. If the gauze dries and the wound becomes painful inside of 4 hours, remove the outer plain bandage and moisten the gauze with the

solution again. Use weaker bichloride of mercury solution for the next and succeeding dressing (1 to 4000). If too strong, the healing granulations may be retarded.

Home Made Aseptic Gauze.—Plain aseptic gauze (absorbent) may be prepared at home by the following methods: For each five yards of ordinary cheese cloth use one-quarter pound common washing soda to sufficient water to cover the gauze. Boil for one-half hour and rinse in several changes of water to remove the soda. This process removes the fat or oil from the fabric and makes it absorbent. After it has been dried it is cut into suitable sizes—strips one yard long and four inches wide are convenient. The gauze is sterilized and packed ready for use in the following manner: Screw top jars with caps are placed in a large bread pan, and the gauze is arranged loosely in the other end of the pan. Place in the oven and bake until the gauze begins to scorch slightly. Remove the pan and all to a table and while hot pack the strips into the jars. Use a pair of forceps or long tweezers and a short wire for this purpose. The tips of the tweezers and wire should be made sterile by passing through an alcohol flame several times, or they may be sterilized by baking with the jars and gauze. Seal the jars and you have a good supply of aseptic gauze ready for instant use. When using the gauze it is well to remove the strips with a pair of tweezers, the tips of which have been sterilized in an alcohol flame. This avoids possibility of contaminating the gauze left in the jars. A quick convenient alcohol flame may be had by saturating a small pledget of cotton in the mouth of a bottle.

Moist bichloride gauze, which is expensive to buy, yet invaluable in case of accident, is made as follows: Prepare and pack the gauze as above. Then prepare a 1 to 1000 solution of bichloride as just explained (burning out the pan with alcohol and using boiled water). Pour this solution over the gauze in the jars until it is thoroughly saturated and allow it to stand for 24 hours. Pour off the excess and seal it air-tight. If dry bichloride gauze is desired prepare the gauze as above, dry it thoroughly in the oven and repack. However, the moist gauze is to be preferred. In using this gauze observe the precaution stated above, *i.e.,* use weaker

antiseptics after 24 hours and. for subsequent dressing. Moist picric acid gauze for burns may be made and kept in a jar for immediate use as follows: Prepare and pack aseptic gauze, as above. Prepare a picric acid solution in the manner described (1 to 200) and pour it over the gauze. Let it stand and then pour off the excess and seal it air-tight.

CHAPTER XIII

HINTS AND KINKS

Hacksaw Blade Reflector—Holding Polished Pipe—Easily Made Soft Hammer Straightening Shaft on Planer—Holding Small Work Without a Vise—Holding Small Work in Vise—Putting on Tools—Illuminated Magnet—Removing Keys—Truing Crankshaft—Repair of Broken Gear Case—Simple Priming Device—Coal Gas for Engine Testing—Warming Manifold for Easy Starting—Stopping Fuel Pipe Leaks on the Road—Use of Tap—Some Threading Kinks—Removing a Stud—Removing Stubborn Nut—Use of Nuts and Bolts—Placing Nuts in Difficult Places—Forming Rod Ends—Winding Springs in a Vise—Cutting Sheet Metal—How to Make a Wiped Joint—Forms of Keys—How to Make Keys and Keyways—Woodruff Key Sizes—Nut Locking Means—Shop Uses of Arbor Press and Wheel Puller—To Make Wood Acid Proof—Sharpening Old Files—Cheap Blackening of Brass—Heat Proof Paint—Etching—Use of Tools—Drilling Holes in Glass—Making a Magnet of a File—Peculiar Cause of Knocking—Rust on Tools—Screw Cutting Gears—Restoring Dull Polished Iron or Steel—Speed of Grindstone—Cleaning Brass Castings—Pipe Joint Cement—Drilling Hints—Body Polishes—Care of Tops—Leather Upholstery—Cloth Upholstery.

Hacksaw Blade Reflector Useful.—When sawing metal with a hacksaw and trying to saw it to a line which has been scribed on the surface the task is found very difficult unless there is good light. A workman in a shop where the writer was employed made a reflector for his saw so that it could throw a good light on the work. A round disk of brass was made as shown at Fig. 468, B. The disk was turned so as to have a collar at the back; a slot was cut through the center of disk so that it could be slipped over the saw. A $\frac{3}{16}$-inch set screw in the collar served to hold the disk in place while in use. Some white enamel was spread over the face of disk to provide a good reflecting surface. A better reflecting surface would result if the disk were nickel plated.

Holding Polished Pipe in Vise.—A very good way to hold pipe or rods having a polished surface is to sprinkle dry plaster of Paris on heavy paper and roll in this paper the article to be held, having plenty of powder between the paper and the polished surface. Place the roll between blocks of wood having hollow faces and clamp firmly in an ordinary bench vise. When removing the paper, if the plaster adheres to the pipe in hard cakes, do not scrape but wash the surface in clean water, which will loosen the plaster and

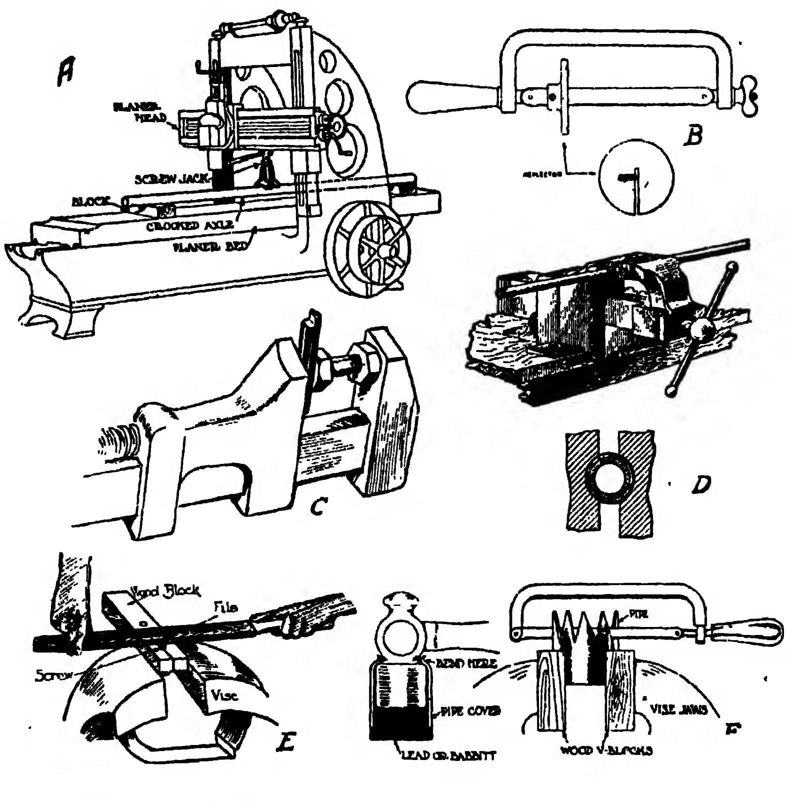


Fig. 468.—Straightening Shaft on Planer at A. B—Hacksaw Reflector. C—Holding Small Work Without a Vise. D—Holding Polished Pipe. E—Holding Small Work for Filing. F—Making Soft Metal Hammer.

leave the pipe in perfect condition. Another method is to place the pipe between pieces of lead sprinkled with plaster, and use a pipe vise for a clamp. A means often employed by mechanics who handle quantities of polished pipe is to face the hollowed wood blocks with soft felt, which is sprinkled with crocus or plaster of Paris to increase the friction. The method is shown in sketch Fig. 468, D, which is self-explanatory.

An Easily Made Soft Hammer.—A soft hammer often comes in handy around an automobile wherever heavy driving is to be done on metal that must not be marred or scratched. Nearly every automobilist carries a hammer of some sort around and is therefore loath to believe that another hammer, even a soft-face one, is a necessity. Whenever metal parts are to be protected he protects the driven piece with wood, leather, or other soft substance. There is nothing handier, however, than having a hammer that is soft and various types have been made for different kinds of machine shop usage, some out of all-metal from pipe and pipe fittings and others similar to the one in Fig. 468, F. To make this one, use an ordinary gas pipe that will easily slip over the head of the hammer and cut off a suitable length so that when finished and assembled the proportions will be about as indicated. Saw out any number of V's from the pipe so that when the teeth are bent inward a spring is formed that will snugly catch the head of the hammer. After the V's are cut out of the pipe, slip the pipe over the head and arrange for pouring the lead or babbitt. The mold is easily made by submerging nearly the whole hammer in sand or by filling the space between the pipe and hammer head with putty. Part of the hammer head should be surrounded with the poured metal in order to insure a good, close fit, but the fit must not be too close. It is well before pouring, to wrap a single thickness of paper around the head, holding it in place with thread or string. Lastly, bend the teeth to produce the spring-locking effect and you have a nice serviceable hammer. As soon as the face is worn it is a simple matter to repair it by melting out the soft metal, and remolding it.

Straightening Shaft on Planer.—It is sometimes possible to straighten a long shaft or tube, such as a propeller shaft or live axle on a planer bed if no straightening machine is available. The

method is clearly shown at Fig. 468, A. The shaft is placed on the planer bed resting on wood blocks supported by that member. A screw jack is placed between the planer head and on the bent portion of the shaft and pressure is thus easily exerted to straighten the defective axle. This is so placed that the high point is directly under the jack so that the pressure exerted by that member will tend to bring the shaft or tube back in line.

Holding Small Work Without a Vise.—It is often necessary to make repairs on the road and some minor part must be securely held for filing or other fitting which is difficult to do if a vise is not available. A simple method of holding a key or pin or similar small parts is shown at Fig. 468, C. A large monkey wrench, which is included in most automobile tool kits, is used as a vise and while it is difficult to secure the proper degree of clamping pressure by the movable jaw adjusting screw alone, sufficient pressure to hold the key securely may be easily obtained by placing a bolt between the wrench jaws and the piece to be held in the manner indicated. Considerable pressure may be exerted by holding the bolt head from turning with one wrench and screwing the nut at the end of the bolt out against the fixed wrench jaw with another wrench. If it is desired to hold a round piece a shallow groove may be filed in the bolt head to prevent it from slipping from the work.

Holding Small Work in Vise.—When filing small screws, bolts, or pins that would be difficult to hold in a vise on account of danger of marring the surfaces the best method is to drill holes in a wooden block to receive the screw and cut a slot from the end of the block down to the hole. When the vise jaws are tightened up, they clamp the piece firmly and it may be filed with ease as indicated at Fig. 468, E.

Removing Keys.—On a number of cars of early vintage, such as the double cylinder Maxwell and on many marine engines, the flywheel is held on the crankshaft by means of jib keys. When it is desired to remove the flywheel as is necessary to withdraw the crankshaft from the engine base when rebushing the bearing, difficulty is sometimes experienced in removing the key. A very effective method of accomplishing this is shown at Fig. 469, A. The key extractor or puller is forged of steel as indicated having two

hooks at the ends formed on curves of different radii. The one having the more gradual curve is used first to start the key while the one having more abrupt curve is employed for withdrawing it. When the key puller is placed between the head of the key and the hub of the flywheel a cam action is obtained by which the pressure of the hammer blows on the other end of the key puller is increased

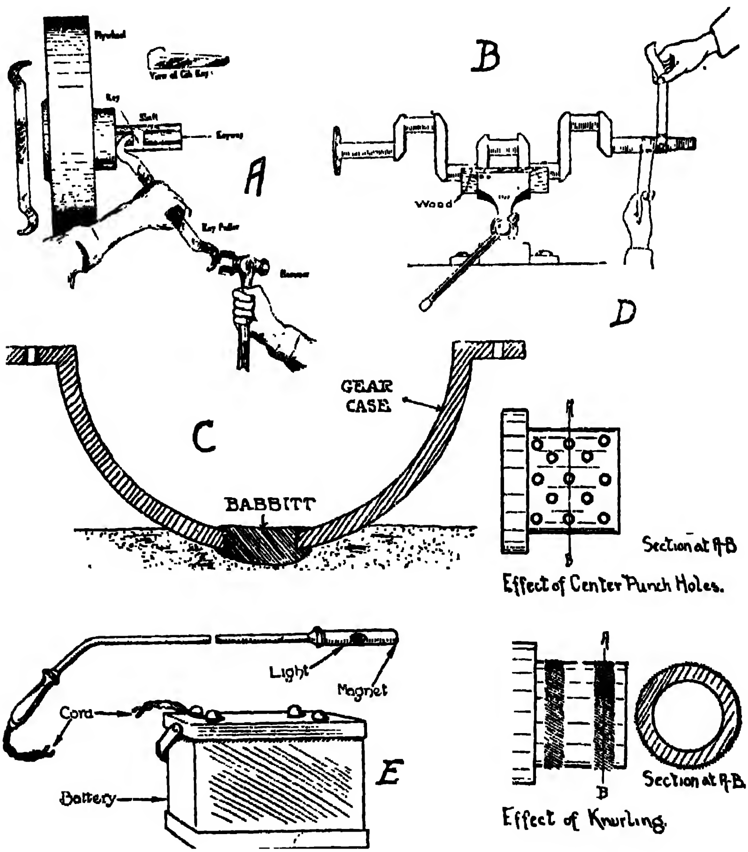


Fig. 469.—A—Removing Jib Key. B—Method of Truing Crankshaft. C—Repair of Gear Case with Babbitt Metal. D—Use of "Putting-On" Tool. E—Illuminated Magnet.

many times and the key easily started. If the key is rusted in place or if it has not been removed for a long time it may be found desirable to heat the end of the shaft with a blow torch or to soak the rusted parts with kerosene.

Truing Crankshaft.—The method of holding a crankshaft when it is desired to true the crank pin journal shown at Fig. 469, B, is a very practical one and is followed by a number of mechanics when overhauling an engine. The journals are often not roughed up enough to warrant dressing them down in a lathe, so the crankshaft may be securely clamped in a vise between wooden blocks and the journals dressed down with strips of emery cloth or with a leather belt or strap covered with oil and abrasive material.

Repair of Broken Gear Case.—An emergency repair of the gear case that has been injured by a nut falling between one of the gears and the bottom of the case is shown at Fig. 469, C. The repairman who made this repair did not have an autogenous welding outfit so the hole was filled up with babbitt metal as shown.

A Putting-on Tool.—How often at some time or other, have mechanics wished for something in the way of a putting-on tool! As it is always easy if a piece is too large, to remove metal in order to bring it to proper size this proposition does not worry even the poorest mechanics. But what is to be done if the piece is too small? A common method and a brutal one is to take a center punch and upset the surface of the metal, in order that it shall be a tighter fit in the hole. A bushing or a rod, if not too small, is often treated in this manner, and may be forced into the hole. A more effective method of "putting on" is by means of a common coarse knurl, knurling the bushing the entire circumference in several places. This will have the effect of expanding the outside diameter almost 1/32 of an inch, if desired, and is much neater and infinitely superior to the use of prick punch marks, which is an unsightly and unreliable method of increasing the effective diameter. The great advantage of knurling is that the metal is equally and uniformly expanded, does not look bad if for any reason the bushing or rod is withdrawn and what is more important for anything that must be a tight fit, it will never work loose.

Illuminated Magnet.—An electric searchlight and electro-mag-

net has been brought out by an English concern and should prove a useful tool in repair shop. It consists of a handle, on one end of which is the magnet, while above the latter is an electric bulb which sends light through two windows, as presented at Fig. 469, E. A flexible cord passes through the instrument and is attached to a storage battery or dry cells. The magnet is utilized to pick up nuts, bolts or pieces of metal that may drop into the crankcase or other places not easily reached by hand, and is said to be sufficiently powerful to attract a good sized wrench. The light facilitates finding the parts, may be used to ascertain the amount of gasoline in the fuel tank or lubricant in the crankcase and to inspect other places. In addition to being handy in the garage it could be included in the tool equipment of a car and used in connection with the roadside repairs.

Simple Priming Device.—Several simple priming devices may be constructed by anyone of average mechanical ability to facilitate motor starting in cold weather. One such equipment is shown at Fig. 470, B, and comprises a dash priming cup, tubing connecting it with the intake manifold, and a spraying device, which is shown separate in the drawing. It will be noted that the last named member is perforated. To utilize the primer a little gasoline is poured into the cup on the dash and the lever turned slightly to admit the fluid, also a little air. The fuel flows through the tube to the perforated member, and upon cranking the engine, the air drawn in through the carburetor and petcock breaks up the fuel, converting it into a rich mixture. It is stated that the motor will start on the second or third crank even in the coldest weather. The material required to install the primer consists of a petcock, which is secured to a plate on the dash; a connector having a tubing and a pipe thread end, ¼-inch annealed copper tubing, and a union. To the last named is soldered a piece of brass tubing which is drilled full of No. 62 drill holes. Its length should be approximately that of the diameter of the intake pipe into which is inserted by drilling and tapping a hole. The manner of installing the parts is clearly depicted in the drawing. It is stated that the equipment described can be made at a slight cost. A simpler installation is shown at A, this consisting merely of a petcock

threaded into the intake manifold. It has the disadvantage that it must be reached to be filled by raising the hood. The owner of a model T Ford states that he has obtained increased mileage by the use of the primer, as the petcock on the dash may be opened to admit auxiliary air. In average running in warm weather he has secured 26.5 miles to the gallon, and 32 miles in long trips.

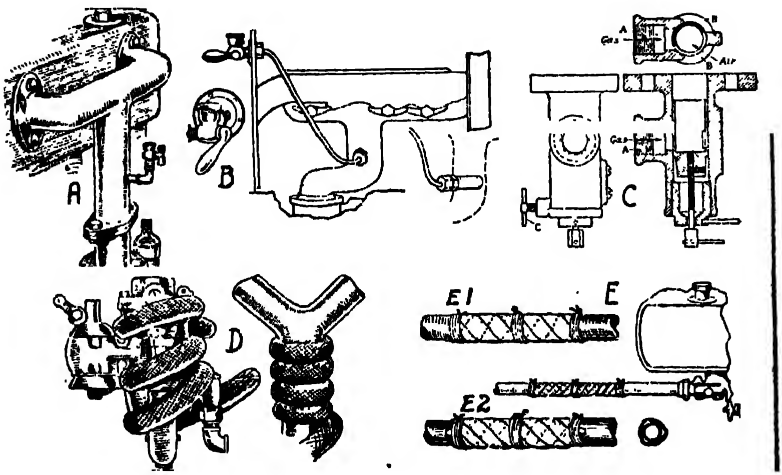


Fig. 470.—A—Simple Priming Device. B—Simple Priming and Auxiliary Air Device. C—Coal Gas and Air Mixer. D—Method of Warming Carburetor. E—Emergency or Fuel Pipe.

Coal Gas for Testing Engines.—The Willys-Overland Co., Toledo. Ohio, uses city gas for testing and "running in" engines in its testing department. The company has constructed a special mixer which fits the inlet manifold and takes the place of the carburetor. This is shown at Fig. 470, C. The housing is a cast iron cylinder having a threaded boss on one side for attaching to the gas supply at A. Level with the gas inlet are two air ports, B. B. Threaded into the bottom of the housing is a plug, the object of which is to rotate a sleeve immediately above it around in one direction or the other as may be required for the adjustment; this

sleeve is connected to the threaded plug by two sliding keys (not shown in drawing).

Running through the plug is a rod threaded at the upper end which permits of the sleeve being raised and lowered as may be required, but which will not rotate it on account of the sliding keys that move up and down in corresponding slots in the plug; the plug is locked in position by the screw, C. When setting the mixer in testing an engine, the sleeve is first rotated by the plug to obtain the correct proportion of gas and air, usually to a position as shown in section AA. Note that the gas supply is considerably smaller than the amount of air allowed. When this adjustment is made, the plug is locked by screw C. Then the speed of the motor can be regulated by raising or lowering the sleeve with the threaded rod running through the plug. This makes a very simple and inexpensive device which is entirely satisfactory. Besides saving fuel, it does away with the danger from split gasoline in the test shed.

Stopping Fuel Pipe Leaks.—One of the simplest emergency methods is to utilize a section of rubber tubing which is slipped over the metal pipe, but if the break be in the center of the line the vibration would tend to chafe the rubber. The latter should be braced by splints and the manner of attachment is shown at Fig. 470, E. Where this is not obtainable a repair may be made with ordinary friction tape. Strips of wood are laid lengthwise on a first winding of tape and in the same direction as the line and the outer tape wound as depicted at E 1, being tied with twine. The wrapping should be snug where the break occurs to prevent leakage of the fuel. A small crack may be treated in a similar manner or by using soap and tape as the former is not affected by gasoline; in fact, a piece of this material is invaluable in the tool kit. Shellac may also be used in conjunction with tire tape. A piece of rubber hose from the acetylene gas line may be used to join the broken pieces of tube temporarily.

Warming Manifold for Easy Starting.—One finds numerous instructions for easy starting of a gasoline engine under conditions of low temperature when the gasoline does not evaporate readily. Some ill advised writers have recommended the use of hot cloths

heated by being saturated with boiling water, others have been advised to heat the manifold with an ordinary blow torch. The necessity of keeping the naked flame away from gasoline is apparent to any one familiar with this liquid and it is also evident that water dripping from a saturated cloth in through an auxiliary air valve so it would get into the carburetor mixing chamber would cause considerable trouble on account of being matter out of place. An excellent method of heating a carburetor or manifold without any danger is to use a tube of cloth or long bag which is filled with sand and placed in an oven after which it may be wrapped around either the carburetor or manifold as shown at Fig. 470, D, without any danger of fire as is present when a torch is used or getting water into the carburetor as is possible when wet cloths are employed as a heating medium.

The Use of the Tap.—The true mechanic can always be known by the way he uses his tools, and care must always be taken that the right way is employed, because improper use has shortened the life of many good tools. Taps and dies are commonly abused, and often broken. You will never see a thorough mechanic using a monkey wrench on a tap. He will tell you that there is a one-sided force against the tap, especially if the metal being threaded is at all hard, that will invariably break the tap. It is obvious that the wrench supplied and called the tap wrench is all that should be used for this purpose, as both its arms are of equal lengths, and there are no bending strains against the tap. Then there is the die: fortunately most of these are used with the proper holder, known as a die stock, and they are not as easy to break as the more fragile tap. The end of the blank rod which it is desired to thread should be carefully filed or turned to a slight taper, so that the die will fit it with ease, and have a chance to start. Then care must be observed to prevent wabbling of the die, which might break some of the cutting teeth, or would cut a very inaccurate thread. When it is desired to cut threads to a shoulder the die may be used the regular way as far as possible and then reversed, which will cut threads right to the shoulder. Never try to start a die with the reverse side, because it will be practically impossible to obtain a good thread.

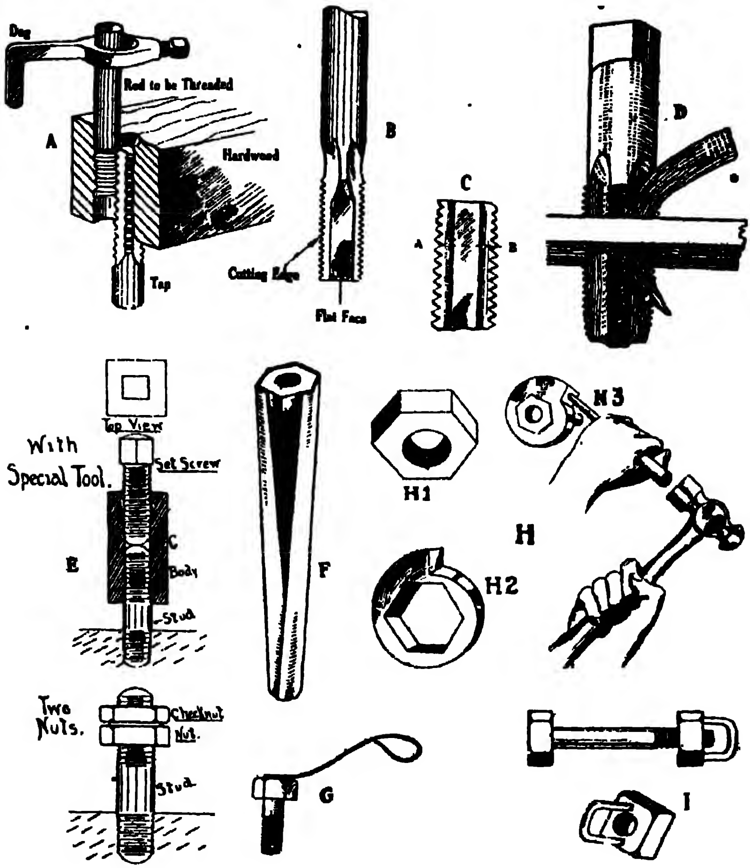


Fig. 471.—A, B, C, D—Illustrating Use of Tap. E—How to Remove Studs. F, G—Placing Nuts and Bolts in Difficult Places. H—How to Remove Stubborn Nut. I—Easily Made Thumb Nut.

The care to be used with a tap or die varies according to the materials to be threaded. If cast iron or brass be tapped, a minimum of the lightest cutting oil should be employed, whereas wrought iron or steel will require the constant use of a cutting oil. Never use machinery or cylinder oil with a tap or die; lard oil

should always be at hand for this use. In iron or steel the tap should be worked in gently, and with quarter turns backward and forward as soon as it begins to take hold. If the hole is deep, care must be used and the tap removed occasionally to clear it of chips. Tap sets are usually composed of three of each size, two of which have an appreciable taper at the end, the other is the same size all the way, and is slightly chamfered at the end. That with the greatest taper or "leading" tap is used first, followed by the next one, which is known as the No. 2 or "following" and last of all the No. 3 or "bottoming" tap. The bottoming tap should never be used except after both of the others have been used as far as possible. A bottoming tap is very useful to clean out or enlarge a thread that is already tapped but which may be a trifle small.

Some Thread Cutting Kinks.—The repairman often has occasion to cut left hand threads in nuts or on bolts and it sometimes happens that a left hand tap or die is not available at the moment. A right hand tap can be used to thread a rod to make a bolt or for tapping a nut with a left hand thread by observing a few simple precautions. The illustration at Fig. 471, A, shows how to thread a rod with a right hand tap so it will act in the same way as a left hand die. Two holes are drilled in a piece of hard wood in such a manner that they cut into each other, the size of the hole being equal to the diameter of the piece to be threaded. The tap is screwed into one and held rigid, the other serves as a guide for the bolt or rod upon which the threads are to be cut, causing it to bear against the outside cutting edge of the tap. By turning the rod in a left hand direction a left hand thread will be cut, both the pitch and cutting edge of the tap being true enough for this purpose. Parallelism of threads will depend on the operator.

When the tap is to be employed in tapping out a nut, the alteration shown at Fig. 471, B and C, is necessary. A four-fluted right hand tap is changed into one having but two cutting edges by grinding off two of the flutes. On considering the remaining two cutting faces, it will be seen that the point of the thread on one side is on a line with the bottom of the thread on the other. This form of tap will cut either right or left hand threads depending upon the direction of rotation. Steel and brass, as well as cast

iron, have been tapped successfully by this method. After a nut is tapped, should it prove too small for the bolt it is intended to fit, it may be easily made larger. A small piece of tin is placed over the end of one of the flutes of the tap, as shown at Fig. 471, D. The tap is "run through" again and it will be found that the piece of tin crowds the tap to one side and cuts a considerably larger hole than before. If the nut should not prove large enough, another piece of sheet metal may be placed over the first one, which has assumed the contour of the threads.

Removing a Stud.—Nothing marks the slovenly mechanic more than the methods he employs in performing his work, as well as the use of the improper tools for different operations. He will cheerfully use a screw driver as a cold chisel or a monkey wrench as a hammer, with but little care of the consequences, both to the tool and the work. It is this class of "mechanic" who will use a Stillson or pipe wrench upon a stud in essaying to remove it from the work, marring the appearance, as well as often destroying its usefulness by injury to the threads. Two methods are shown at Fig. 471, E, of removing a stud without damage to any part, the simplest being by the use of two nuts, the more mechanical by means of a simple device or tool. Where two nuts are employed one is used as a check or lock nut for the other. The two nuts are tightly locked to each other and the pressure to remove the stud is applied to the lower one. It may be necessary to hold the top nut by means of another spanner or end wrench to prevent it turning upon the stud instead of with it.

A very efficient and simple device for removing studs may be made by any ordinary man familiar with the use of tools. This consists of a body C which may be made of a piece of hexagonal or square stock; either bronze or steel is preferred to cast iron, because the threads are much stronger in such metals. A hole is drilled through of suitable size and a tap is run down through the hole and a suitable thread cut to fit the stud to be removed. A cap or set screw (A) completes the device. To use, the body is screwed upon the stud for a certain distance and the set screw is then screwed tightly against the end of the stud. If the body is made of round stock, flats should be filed on the sides in order to

hold a wrench. If square stock is available, it will be preferable. This device is very handy and should be made in several sizes, for the various standard stud sizes which are mostly used in mechanical work. A set should form part of every mechanic's personal kit because they are inexpensive, and when required are worth their weight in gold.

Removing Stubborn Nut.—While a stubborn stud or sheared bolt is difficult to remove, one can usually unscrew a nut without much trouble, even if it has become more or less rusted in place. A good method to take off a nut that seems to resist being parted from its stud or bolt more than usual is to heat an open spanner that fits the nut and let it rest against the nut for a few minutes. The heat will sometimes expand the nut without producing corresponding expansion of the bolt and it may be unscrewed. The spanner or end wrench may be heated in a blow lamp flame, and while this kink is very old it is not generally known. One should not heat a hardened wrench or an adjustable member as it may be rendered unfit for use. The blow lamp flame should not be applied to the nut direct because the bolt will be heated and will expand as well as the nut. Kerosene may be poured around the threads with good results, especially if the nut has rusted in place. Several alternate heatings and applications of kerosene oil may be needed before the nut is loosened and if it still resists, a light tapping with a hammer on all the facets while it is hot may assist in having it become looser on the threads

Use of Nuts and Bolts.—Most of the parts of the motor car are held together by what is known as a bolt and nut, especially if the component is one which must be removed from time to time for inspection, adjustment or repair. There is no part of the car which is subject to more abuse than the bolts and nuts, and these parts are often damaged by carelessness or ignorance so that new ones must be used. This is not a serious matter if the bolt is a standard form, but if a special size fitted with an odd thread, it must be evident that a new one can only be obtained from the factory or made at the local machinist's at some expense. If difficulty is found in causing a bolt used to hold together two parts to fit the holes with ease, the chances are that the two pieces are dis-

placed angularly, and one should not attempt to put in the bolt by brute force. A good plan is to use a taper punch, smaller than the bolt at the point and larger at the other end, this is first driven into the hole, and tends to bring the parts into proper alignment so that the bolt may be easily inserted.

Many bolts and studs and their nuts are damaged by carelessness in starting the nuts cross threaded, and then using a wrench to forcibly turn them on. Nuts should be carefully started with the fingers and one should ascertain that the threads engage properly before pressure is applied. Bolts are very often spoiled in driving them out from the parts in which they are located. If they do not start readily one is often tempted to use a hammer upon them, with the result that the ends of the threads are burred over and one has trouble in replacing the nut. A stick of hard wood, a piece of fiber, or a junk of soft brass, copper or lead should be interposed between the hammer and the end of the bolt to prevent damage of this kind. Most mechanics have either a lead or copper hammer for this purpose, and the writer has seen motorists' kits which had this useful tool, or its equivalent, a wooden mallet. There are many uses for such a tool, as driving on or off the various soft parts, either of brass, aluminum, or cast iron, which would be dented and damaged by the steel hammers generally used.

Starting Bolts and Nuts in Difficult Places.—Recently while working on an automobile it was found difficult to get a bolt started in its place, and when the writer had about decided to remove other parts to enter the bolt, the following scheme of overcoming the difficulty was tried. A piece of wire was procured and one end lightly soldered to the bolt head. This served as a handle for placing the bolt and was easily removed by giving the wire a few turns. The same means can be used to enter bolts and pins in places not easily accessible, the time of preparation being small as compared with the practical value of the device. (See Fig. 471, G.) A simple method of starting a nut is shown at Fig. 471, F. The holder is made of sheet metal, rolled into a tube. A nut is then inserted in one end and the metal hammered to the shape of the nut. Any length of metal can be used, as desired. In use, the shaped end of the metal is slipped over a nut and a slight pressure

suffices to screw it down over bolt. For starting nuts on the end of a bolt in a location not easily reached with a wrench the simple tool shown at Fig. 481, II, will be found valuable. This is made of steel and has a projecting lip against which a drift may be placed as at II 3. The nut may be started by hammer blows without damage. Burred threads on a bolt may be cleaned up by using an extemporized die made from a nut of the proper size as at II 1 by cutting a series of three grooves in the threads with a three cornered file to provide cutting clearance and then case-hardening the nut interior.

Forming Rod Ends.—Many of the minor control rods such as is used for advancing the timer, manipulating the throttle or working the muffler cutout are simple steel rods with the ends bent over to be pushed through the eye of the levers they connect. A simple method of making these rod ends is shown at Fig. 472, A. A block of steel is drilled with three or four holes to conform to the sizes of rod ends most generally used. It is well to have the holes about one sixty-fourth inch larger than the rod size. The writer would advise making holes, one-eighth inch, three-sixteenths inch. quarter-inch and five-sixteenths inch in the block. When making the rod end, the block is held in the vise and the rod, which is either Norway iron or mild steel is thrust into the block to the desired depth and then bent over with a hammer as indicated. In bending the rod this should be done slowly and with as much care as possible and the rod should preferably be heated to a red heat before bending.

Winding Springs in Vise.—Small springs are often needed in repairing automobile parts and in some cases a spring winder or lathe is not available for making the spring. The illustrations at Fig. 472, B, are reproduced from a recent issue of Machinery and the device shown is a very practical one as it uses parts found in every garage. A rod A is selected that will give the correct inside diameter to the springs. The diameter of this rod must be determined experimentally as there must be some compensation for the enlargement of the spring when released. This, of course, means that the rod must be less in diameter than the inside diameter of the finished spring. The rod is bent at one end to form a crank.

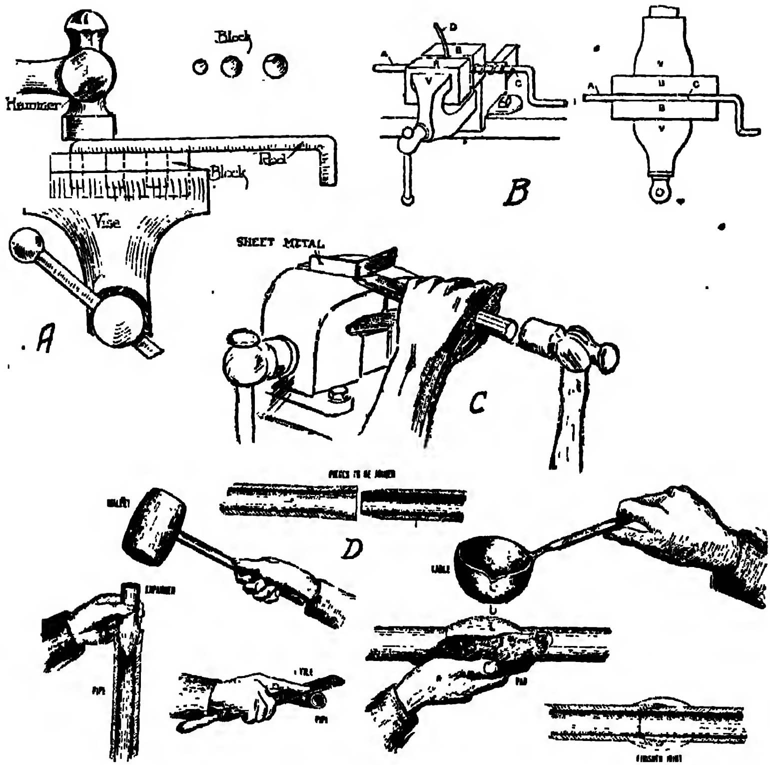


Fig. 472:—A—Method of Forming Rod End. B—Winding Spring in a Vise. C—Cutting Sheet Metal. D—How to Make a Wiped Joint.

A hole C is drilled near the crank end which shou'd be large enough to allow the end of the spring wire to enter. The tool is clamped between the vise jaws B and the wood blocks D. The rod A should be clamped with the crank as close to the blocks as possible with the wire in a vertical position. As the crank is turned, a groove is cut into the wooden block which acts as guide for the wire D, the number of coils or pitch of the spring being determined by the amount of inclination of the wire. The greater the inclination the wider the spacing. The first turn of the crank must be very carefully made as it determines the pitch.

Cutting Sheet Metal.—When a strip is to be cut from sheet

metal, instead of laying the sheet down on an anvil or bench plate and cutting with a chisel by hammering against the chisel which is placed vertically in respect to the block the method shown at Fig. 472, C, is recommended. This gives a shearing cut which will make a smoother edge and not be liable to damage the edge of the chisel as is done when that tool is driven through the sheet metal and into the backing block. The piece of sheet metal to be cut is clamped between the jaws of the vise, just enough of the metal being allowed to project above the vise jaws as corresponds to the width of the piece to be cut. By cutting with a shearing action in the manner indicated it will be possible to cut off the strip smoothly with very little exertion and without damaging the chisel edge.

How to Make a Wiped Joint.—The wiped joint is a form that is very popular with plumbers when joining lead pipes, but it may also be used to advantage by the repairman in making joints in the copper tubing used for acetylene gas oil and fuel lines and in some cases the larger copper pipe employed for water manifolds. The various steps are shown at Fig. 472, B, the proportions of the pipe or tube being greatly exaggerated in order to make the process clear. The first step is to expand one end of the tube by driving in a small conical expanding tube, taking care to hold the pipe firmly between wood blocks in the vise while this operation is in progress and to expand the pipe by a series of light taps rather than heavy blows. If the expanding tool is held too hard it is apt to spread the pipe. The end of the tube to be joined with that one which has been previously expanded is filed down tapering in order to fit the expanded section of the other piece. The parts are well coated with soldering flux and molten solder is poured on the joint from a small ladle, this being wiped by a pad of felt which is well waxed and which is used to wipe the molten metal into a symmetrically shaped mass to form the substantial joint as shown in the sectional view at the lower right hand corner of the illustration. If care is taken to have the pieces of pipe cleaned before they are joined and to have reasonably close fits between the male and female taper a very satisfactory joint may be made with a little practice.

Forms of Keys.—Many parts of automobiles which must be

removed from the pieces to which they are fastened and by which they are actuated are held by a method of fastening called "keying." Various forms of keys are shown at Fig. 473, that at A being a form made from ordinary key stock which may have either rounded ends or square ends depending upon whether the key is to be set into a keyway machined into the center of the shaft or at one end. If the keyway comes in the middle of the shaft, a round end key such as shown at A is generally used. If the keyway is at the end of the shaft, the key is apt to be a form having square ends. Key stock is procured in various standard sizes and is usually made smooth enough when manufactured so that no great amount of fitting is needed to insert it in the keyway. The key shown at B is known as the Woodruff key and is a very popular form in automobile construction. It is commonly used for securing such parts as gears, cams, and rocker arms to shafts. The taper pins shown at C is a favorite method of retaining brake actuating and control levers to the shaft operating them. The straight pin shown at D may be used in two ways, it may be driven entirely through the shaft and the hub of the lever and then headed over or it may be driven into a drilled hole which is made after the gear or piece it is to hold is in place on the shaft, the hole being drilled in such a way that half of it is in the gear and the other half in the shaft. The use of a taper pin is clearly shown at F while that of the round pin or key shown at D is outlined at G. The half round keyway for the Woodruff key is shown in the taper end of the shaft outlined at E as is the method of making a template to obtain the radius of the Woodruff keyway when it is desired to fit a new Woodruff key or to determine the size of the keyway if the old key is lost.

The method of making the taper pin lock is a simple one. A straight hole is drilled through the boss of the lever and the shaft, the drill size being the same as that of the small end of the taper pin. Taper reamers may be obtained to conform to the taper of the standard taper pin and these are employed to produce the correct taper in the straight hole in order that the corresponding taper pins may be a tight drive fit in both shaft and lever boss.

How to Make Keys and Keyways.—The method of laying out

a keyway when the rounded end key shown at Fig. 473, A, is to be placed in a shaft is shown at Fig. 474, A. The outline of the key is scribed on the shaft, care being taken to have the curved end a half circle whose radius is equal to half the width of the key. For example, if the key is supposed to be one-quarter inch wide and two inches long the first operation will be to describe a straight line along the shaft and to indicate thereon the useful length of the key which is that of the straight portion by center punch

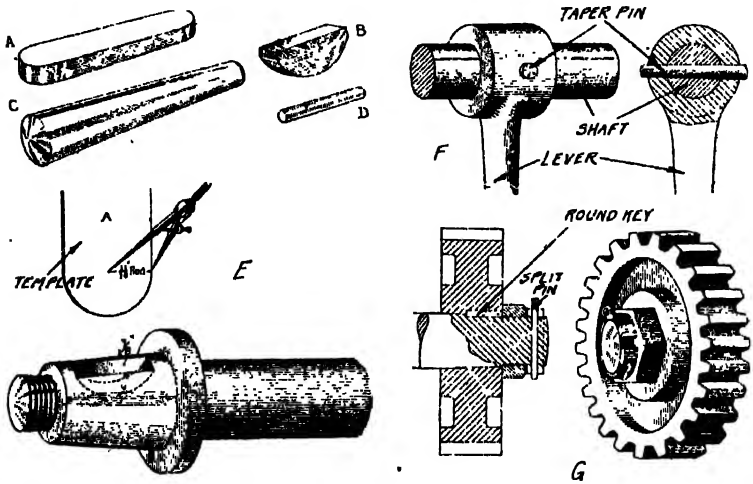


Fig. 473.—Forms of Retaining Keys and Their Use.

marks on the line. The dividers are then set to one-eighth inch radius and circles are drawn using the punch marks as centers. The sides of the circles are then joined by lines parallel to the center line. The next operation is to drill a series of quarter inch holes into the shaft as shown at Fig. 474, B. These are cut out by means of chisels such as shown at Fig. 474, C. The operation is started with a narrow chisel, followed through with the medium width chisels and finished off with the wide one which is accurately ground to the correct width of the keyway. A piece of quarter inch keystock is then obtained cut to the proper length and the ends rounded off with a file or on an emery wheel, to conform to

the shape of the keyway. The method outlined is of course, used only where regular keyway cutting machinery is not available, as would be the case in a small repair shop where milling machines or shapers are not included in the machine tool equipment. The method of making a keyway in the end of the shaft is similar to that for making one in the middle of the shaft except that it is

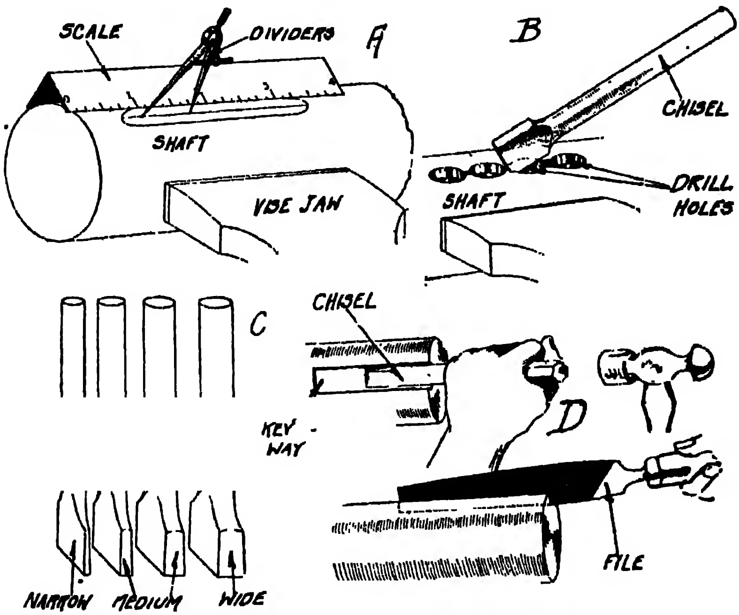


Fig. 474.—Methods of Cutting Keyways in Shafts without Machine Tools.

much easier to chisel out the keyway with a cape chisel and finish it with a file as shown at Fig. 474 D.

The Woodruff key may be obtained in a wide variety of sizes and in different materials. It is a very simple form to make if a key of the right size is not available. A very satisfactory Woodruff form key may be made from a bar of round stock of the desired material and radius as indicated at Fig. 475, in views A to F, inclusive. The first step is to saw into the end of the rod as shown

at A, then to cut into the side of the rod with the saw as shown at B, this permits the piece of stock to break away as shown at C. Of course, the key is cut wider than the keyway it is to fit as well as longer than the regular size key. The operation of filing the sides and face to produce the finished key shown at F is clearly outlined at D and E. The keyway for a Woodruff key can be made

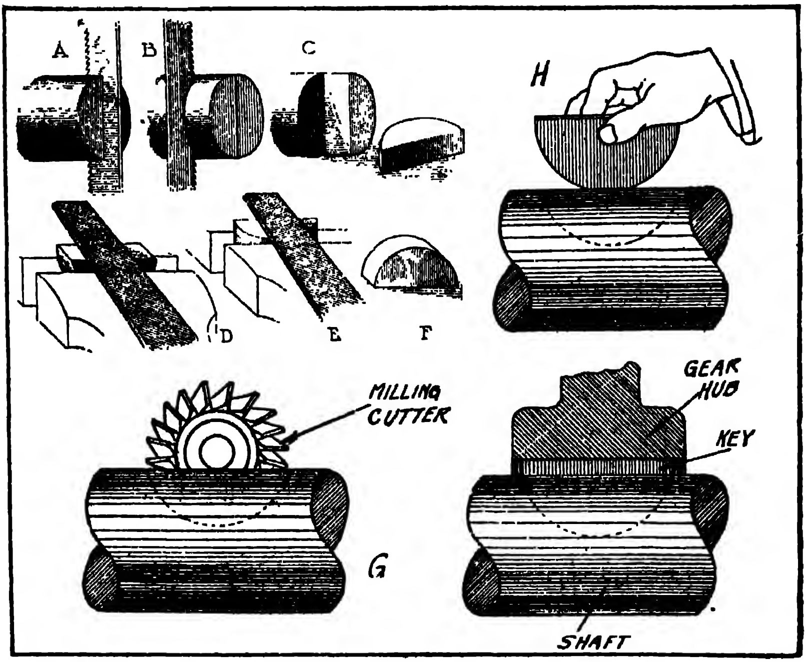


Fig. 475.—How to Make a Woodruff Key, Cut the Keyway and Method of Using.

only by a special milling cutter made for the purpose. It is not necessary to have a milling machine to use this milling cutter as very satisfactory results can be obtained by putting it in a lathe or drill press chuck. The depth to which the cutter is fed into the shaft is clearly shown at G. The key is then placed in the keyway as outlined at H and the hub of the part it is to retain is forced over the key and shaft as shown in the lower right hand corner of Fig. 475. Care must be taken when fitting any form of retaining

pin or key to have this a tight fit in its keyway as if keys are fitted loosely so that some degree of movement is permitted between them and the keyway and the shaft or the part it drives, sufficient lost motion may develop so the key will be sheared off. This applies especially to keys subjected to variable or sharp loads as in those employed for holding flywheels, driving wheel hubs, or transmission system parts.

Woodruff Key Sizes.—Each year sees the use of more and more Woodruff keys for fastening gears and similar parts to round shafts, for which reason the various sizes are of considerable interest. A table herewith gives the various sizes which are referred to in the sketch above, the letters in the table corresponding with those in the figure. There are 30 standard and many special sizes.

No. of Key	Diameter	Thickness	Depth in Gear	Less than ½ Diameter
	a	b	c	d
1	.500	.0625	.0312	.0468
2	.500	.0937	.0468	.0468
3	.500	.1250	.0625	.0937
4	.625	.0937	.0468	.0625
5	.625	.1250	.0625	.0625
6	.625	.1562	.0781	.0625
7	.750	.1259	.0625	.0625
8	.750	.1562	.0781	.0625
9	.750	.1875	.0937	.0625
10	.875	.1562	.0781	.0625
11	.875	.1875	.0937	.0625
12	.875	.2187	.1094	.0625
A	.875	.2500	.1250	.0625
13	1.000	.1875	.0937	.0625
14	1.000	.2187	.1094	.0625
15	1.000	.2500	.1250	.0625
B	1.000	.3125	.1562	.0625
16	1.125	.1875	.0937	.0781
17	1.125	.2187	.1094	.0781
18	1.125	.2500	.1250	.0781
C	1.125	.3125	.1562	.0781
19	1.250	.1875	.0937	.0781
20	1.250	.2187	.1094	.0781
21	1.250	.2500	.1250	.0781
D	1.250	.3125	.1562	.0781
E	1.250	.3750	.1875	.0781
22	1.375	.2500	.1250	.0937
23	1.375	.3125	.1562	.0937
F	1.375	.3750	.1875	.0937
24	1.500	.2500	.1250	.1094
25	1.500	.3125	.1562	.1094
G	1.500	.3750	.1875	.1094

These sizes vary from .5-inch diameter and .0625-inch thickness up to 1.5-inch diameter and .375-inch thickness. The general shape of the keys is that of a coin cut into halves, although to be exact the half is not complete, as the sketch shows. The key is set down into the shaft less than its full depth by almost the amount of its thickness, so that the portion projecting above the shaft and into the gear or other part is nearly square in section.

One great advantage of this form over a square ended key is the ease of placement or removal, a slight tapping on one end, caus-

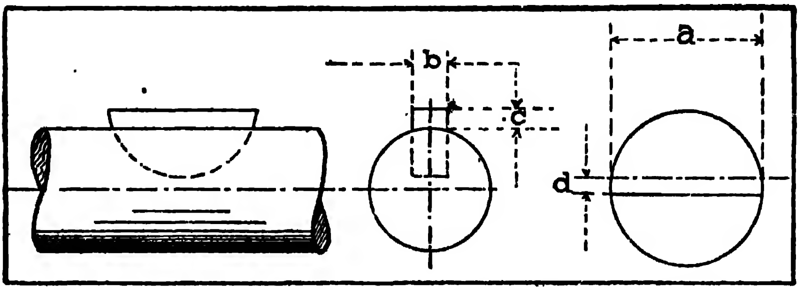


Fig. 476.—Diagram Showing Principal Dimensions of Woodruff Keys to Accompany Table of Sizes.

ing the semi-circular form to rise out of the other end of the key seat, until it is loose enough to be picked out.

Nut Locking Means.—There is no mechanism in which it is more important to keep the nuts, bolts and other fastenings tight, than in the automobile, because these are operated at high speeds, over rough roads and are subjected to considerable vibration. As is well known vibration in machinery causes the various parts to loosen. While there are a number of methods of locking nuts and bolts to keep them from becoming loose, a practical method for use in automobile construction must be such that the nut can be removed when desired without destroying the nut lock. For example, it is possible to lock a nut securely by having the bolt a little longer than is needed and by riveting the projecting end after the nut is screwed in place. While this insures against loss of the nut it is apparent that when the nut is to be removed, it is first necessary to chisel or file off the riveted portion of the bolt.

A large number of practical locking means for nuts and bolts are shown at Fig. 477. The "Grip nut" which is shown at A is a supplementary nut of peculiar form which is put on over the regular nut. These are blanked out of a bar of steel having an arch running through the center and the nut is threaded through this arch. When it is screwed in place it is deflected by pressure so as to produce a locking friction upon the thread. When screwed down tightly it is impossible for the nut to vibrate off though it may be easily removed with a wrench. Another device of similar form which is known as the "Hugtite" is shown at H. This looks like a thin nut but instead of having threads there are two tongues extending from either side toward the center, engaging the bolt threads. These tongues are formed so that when the locking member is in place on the bolt its faces are not parallel to the face of the nut as one edge touches the top of the nut and the other does not. If the big nut tends to loosen from vibration it will bear against the locking member and the friction produced between the tongues and the bolt threads will prevent the main nut from coming off.

The castellated nut and cotter pin which is shown at C is so widely known and used that it requires no description. Lock washers have been devised in many forms, typical examples being shown at B, I, J and M. These for the most part are made of spring steel which must be flattened out when the nut is screwed down tightly. Some of these depend merely on spring pressure, though others have barbs or ribs which are intended to dig into the nut and prevent it from coming loose. The ribbed washer is put in place with the rib uppermost and when the nut is screwed down the rib forces a small part of the metal from the nut into the thread and in this way locks the nut securely. The other forms such as the "Positive," "National," and "Hobbs barbed" depend upon the principle of one point digging into the nut and the other into the metal the washer seats on. The "Columbia" lock nut is a very popular pattern and is virtually a double form. The nut proper is split and tapered on the outside and fits into the hexagonal outer shell which is tapered inside as shown at E. When the nut is screwed down tightly the inside part sliding on the shell

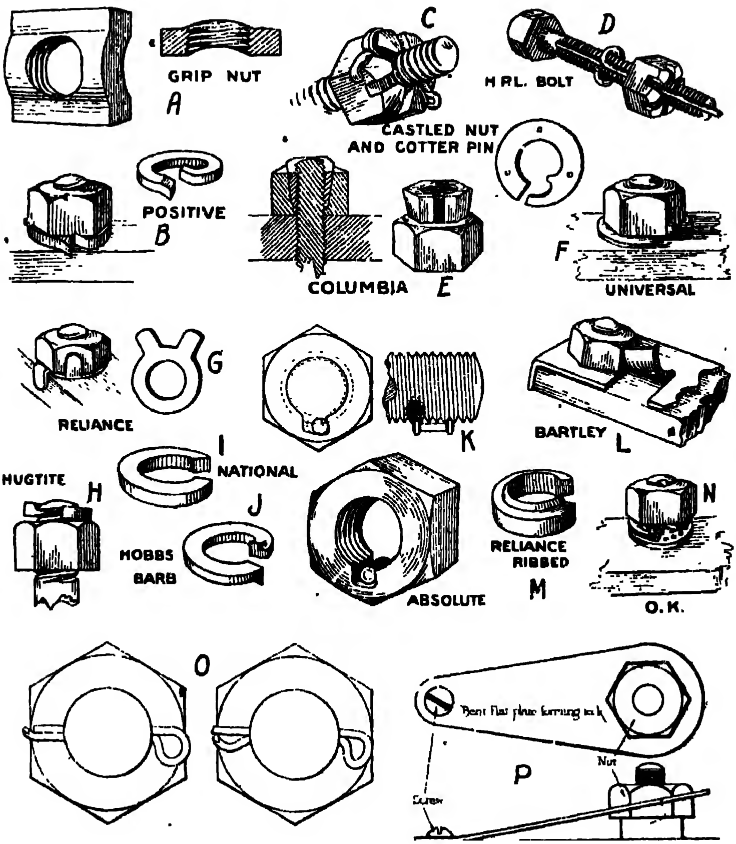


Fig. 477.—Nut Locking Means that Have Been Widely Used.

draws the threaded portion together and forces the threads of the nut into a close contact with the threads of the bolts. One of the very good features of this lock nut is that it may be easily removed with a wrench, yet absolutely cannot come loose or harm the thread.

Another form of lock nut which is shown at K is known as the "Absolute" and works on the principle of utilizing the locking properties of a rolling wedge. There is a recess cut in the inner surface of the nut in which a locking pin travels, this being of

such size that when the nut is screwed onto the bolt, the angle sides of the locking pin heads fit into the threads of the bolt. The flat surfaces of the locking pin travel against the angle top of the recess of the nut, rotating in its deepest portion. The top of the recess is at such an angle that the nut is automatically and continuously locked against any backward motion which serves to wedge the pin more tightly in position. It is easy to take this nut off, as this can be accomplished by inserting a small brad or piece of wire into the recess to prevent the pin from rolling up into the small part of the recess when the nut is unscrewed. This nut is more practical in the larger sizes than it is on the small size nuts widely used in automobile construction.

Another system of locking depends upon preventing movement of the nut after it has been screwed into place by a projecting tongue bent up against the nut. As an example we have the "Universal" washer which is shown at F. This looks considerably like a spring washer but differs in that it has a little tab or tongue that the nut rides over as it is screwed into place and when the nut is tight the tongue sticks up and prevents the nut from turning back. This washer is made of hardened steel and has projections on its under side to prevent it from turning. Another type of locking device that is very simple is the "Reliance," shown at G. This is nothing more than a plain washer with a couple of tongues extending from the outer periphery which are bent against the nut and the piece the nut bears against, in the manner indicated. The "Bartley" lock shown at L has been used for some time on railroads. This is nothing more than a plate which slips over the bolt like an ordinary washer and when the nut has been drawn up tight there is a little tongue which can be turned up against one of the facets of the nut to keep it from turning. The "O. K." lock nut consists of a spring washer having the end formed to fit into little depressions formed in the nut and in a supplementary washer which is keyed to the bolt, which is slotted. The corrugations in the bolt head and supplementary washer prevent the nut from turning even if it is not screwed down as tightly as is necessary with the regular form of spring washer.

A form of lock which works somewhat on the principle of the

castellated nut and cotter pin is shown at B. In this method the bolt is slotted and a piece of strong and ductile wire is placed in the slot, the lower end of which is formed into a washer to fit between the nut and the surface through which the bolt is passed. When the nut is drawn up tight the end of the wire, which lies into the bolt slot is bent into one of the castellations of the nut. The "Campbell Self-Locking" cotter pin which is shown at Fig. 477, O, has been designed to replace the well-known spring cotter. This is of such form that it may be easily inserted in a hole and when in place it can be locked by hitting the loop or eye with a hammer which drives the short leg down, springing the bent leg and forming a very effective lock. This cotter is made of half round stock, the same as the ordinary type, but has an offset eye and the two limbs forming the body of the pin are of unequal length. The pin may be easily removed when desired by inserting a screw driver blade in the flattened eye and pulling the straight leg out of contact with the bent leg which makes it possible to withdraw the pin. A method of locking a nut which is sometimes used is shown at P. In this a bent plate having a hexagonal hole to fit the nut is held tightly at the other end by a screw threaded into the piece the nut retains or some other fixed part. This is seldom used as it is more bulky and cumbersome than many of the simpler lock washers described.

Shop Uses of Arbor Press and Wheel Puller.—One of the useful tools and one of the simplest included in the automobile repair shop equipment is an arbor press that can be adapted to a wide variety of work. A form of press, especially devised for automobile repair shop work is shown at Fig. 478. This has sufficient height so that long pieces may be inserted between the ram and the bed while the supports are spaced sufficiently far apart to make it possible to insert relatively bulky articles. The press is adjustable as the bed plate may be moved up and down on the side rails in order to vary the opening between the movable member that exerts the power and the work holding portion. The press is also suited for a variety of machine shop operations. The view at A shows the manner of forcing a driving gear off of the shaft of a rotor. As will be noted the bed is placed down near the base which makes

possible the introduction of the long roller. The gear to be forced off is supported by two iron bars which rest on substantial wooden blocks carried at either side of the roll. The pressure is exerted against the end of the shaft, this forcing the shaft from the gear. The use of the press in straightening a bent rear axle housing is shown at B and on front axle work is shown at D. At C the opera-

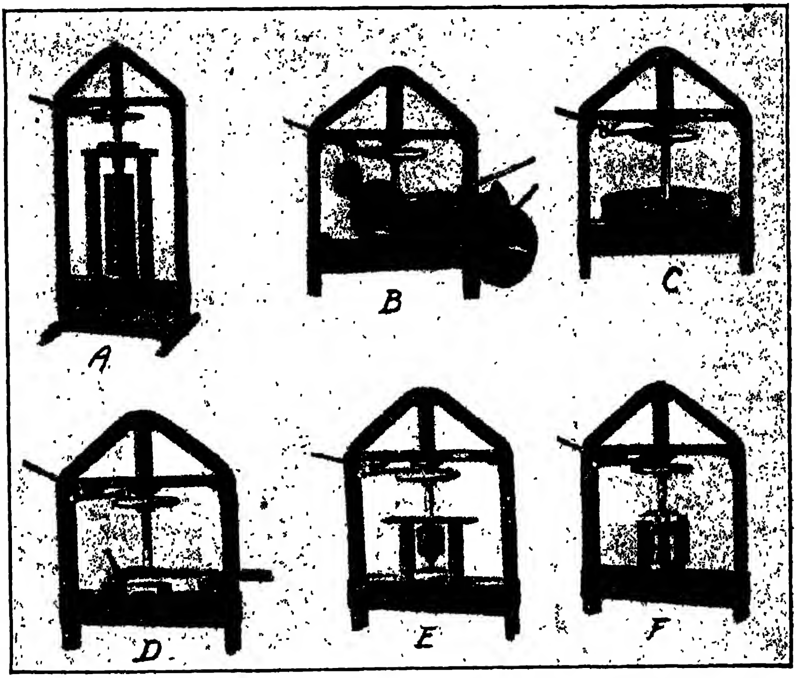
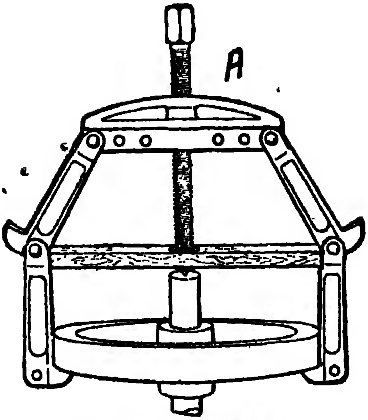


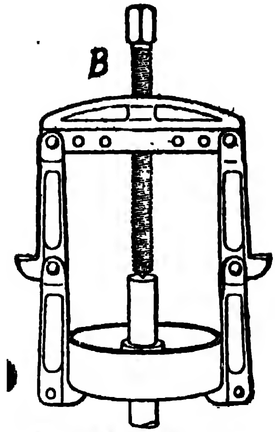
Fig. 478.—Uses of Arbor Press in Automobile Repair Shop.

tion of pressing in a bearing cup in a wheel hub is clearly shown. The manner in which relatively small parts may be handled is clearly outlined at E where a gear is being forced off of the armature shaft of a starting motor and at F where the constant mesh gear is being removed from the countershaft of a gear set.

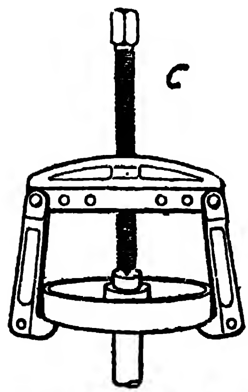
The wheel puller is also a very useful appliance, special forms suited for repair shop work are shown at Fig. 479. The type shown at A is a two armed puller having two sets of arms, the lower



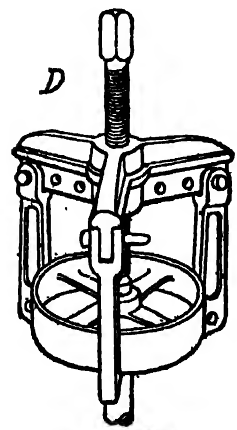
For Work of Large Diameter (a piece of wood being used as a Spreader).



For Work Beyond Reach of One Set of Arms.



Removing Work Near End of Shaft.



Three-Arm Puller.

Fig. 479.—How to Use Wheel and Gear Pullers.

set being attached to the upper arm as indicated. This makes it possible to handle work of relatively small diameter that is beyond reach of one set of arms as shown at B or on work of large diameter that would be beyond the capacity or spread of the beam when used as at A. In this case a piece of wood is being used as a spreader

for the arms. It is relatively easy to move work near the end of the shaft, this involving the use of only one set of arms as shown at C. The use of the three armed puller, which is a superior form for general service to that shown at C, inasmuch as it is not apt to rock over to one side or the other when the pressure is applied is shown at D.

To Make Wood Acid Proof.—Some storage batteries are carried in wooden battery boxes on cars and annoy the owners by leaking or slopping of the acid. To make the wood acid proof take six parts of wood tar and 12 parts resin, and melt them together in an iron kettle, after which stir in eight parts of finely powdered brick dust. The surface to be covered must be thoroughly cleaned and dried before painting with the warm preparation.

Sharpening Files.—Lay dull and worn files in a solution of sulphuric acid, consisting of one part acid and two of water. Let them stand over night, then rinse in clear water. Put the acid in an earthenware vessel. To resharpen old files wash them in warm water to remove the grease and dirt, then rinse in warm water and dry by heat. Put 1½ pints of warm water in a wooden vessel, put in the files, add 3 oz. of blue vitriol, finely powdered, and 3 oz. of borax. Mix well and turn the files so that every one may come in contact with the mixture. Add 10½ oz. sulphuric acid and ½ oz. of vinegar. Remove the files after a short time, dry, rub with olive oil, wrap in porous paper. Coarse files should be kept in the mixture for a longer time than the fine ones.

The Cheap Blackening of Brass.—The following solution for blackening brass is nothing new; in fact it has been known for a long time. Owing to its cheapness, ease in working and adaptability for many purposes, it has been deemed advisable to bring it again to notice. Many platers of course will recognize it as an old solution known to the plating industry for many years, but they may not have realized its advantages for some classes of work. The solution is made as follows:

Water	1 gallon
Sugar of lead	8 ounces
...osulphite of soda	8 ounces

The solution is used as hot as possible and the brass work is simply dipped in it and allowed to remain until black. This takes about a minute or less. The articles are then rinsed in cold water, then in hot water and dried. If the pieces are scratch-brushed dry, the black deposit will have a high luster. When dipped into the solution, the surface of the brass article becomes yellow, then blue and finally black. The articles should always be lacquered as the black deposit is likely to oxidize and fade if not; but if coated with lacquer, it seems to be quite permanent. For a cheap class of goods that require a black finish, this solution can frequently be used to a good advantage. It requires no electric current used as a dip. The color, to be sure, is not a coal black, but resembles a graphite black more than anything else and has a slight gray shade. It is sufficiently black, however, to answer many purposes and it is so easily applied that it can be used on cheap goods with only a slight increase in cost.

Heat-Proof Paint.—To make a good cylinder exhaust pipe paint, use two parts of black oxide of manganese, three parts of graphite and nine parts of Fuller's earth, thoroughly mixed, to which add a compound of 10 quarts of sodium silicate, one part of glucose and four parts of water, until it is of such consistency that it may be applied with a brush.

Etching.—To etch iron or steel mix one-half ounce of nitric and one ounce muriatic acid. Shake well, and it is ready for use. Cover the place to be etched with melted beeswax and when cold write the inscription plainly in the wax clear to the metal with a sharp instrument; then apply the mixture with a feather, carefully filling each letter. Let remain from one to ten minutes; then throw on water, which stops the etching process, and remove the wax.

Use of Tools.—Never use a tap in a cored or rough hole. Run a heavy flat drill through to take out scale, sand or projections. Use plenty of good lard oil in cutting threads with a die. Many times a die tap is ruined the first time it is used, because there was no oil put on the work. Never use taps in any metal without using plenty of good oil. The tap will gauld in any metal and tear the threads off unless well oiled. Never draw a monkey wrench

backward from the jaws. Always pull toward the jaws, otherwise the bar may be bent. Never use a reamer on pipe of any kind. The scale inside of the pipe, caused by the flux used in welding or brazing, is as hard as glass and no reamer made is hard enough to cut it.

Drilling Holes in Glass.—Holes of any desired size may be drilled in glass by the following method: Take a small three-cornered file and grind the points from one corner on the bias from the other and set it in a brace, such as employed in boring wood, etc. Lay the glass in which the holes are to be bored on a smooth surface covered with a blanket or some other similar material, and begin to bore the hole. When a slight impression is made on the glass, place a disc of putty around it and fill with turpentine to prevent heating by friction. Continue boring the hole, but do not press too hard on the brace when drilling.

Making a Magnet of a File.—Small nuts or washers or other small parts, which have fallen into the crankcase may often be removed without the necessity of dismantling the engine by means of a magnet. By taking about a dozen turns of one strand of the cord to which a lighted electric lamp is attached around a file it will be magnetized quite strongly enough for all practical purposes.

Peculiar Case of Knocking.—The car was a popular four-cylinder model about a year old. It was brought to the shop for a thorough overhauling, and for taking up all the bearings. When the job was complete and the engine operated, a very severe knock developed that sounded exactly like a loose bearing. After considerable experimenting, it was found that one of the pistons touched a shoulder in the top of the cylinder, this was because the packing between the cylinder and crankcase had been reduced in thickness a trifle. A thicker packing cured the trouble.

Rust on Tools and Work.—Vaseline, to which has been added a small amount of powdered gum camphor, heated over a slow fire, will prevent rust on tools. A mixture of one pound of lard, one ounce of gum camphor and a little lampblack melted together will protect bright work from rust. Other formulæ are: A mixture of lard and kerosene in equal parts, a mixture of tallow and white

lead, and of tallow and lime. Smear the parts to be protected with any one of these mixtures.

Screw Cutting Gears.—Multiply the number of threads cut by equal gears, as indicated on the index, by the number that will give for a product a gear on the index. Place this gear on the spindle or stud. Multiply the number of threads per inch to be cut by the same number and put the resulting gear on the screw. Thus, if a lathe cuts four threads by equal gears and 13 threads per inch are wanted then multiply by five, showing that to cut 13 threads per inch would require a gear of 20 teeth on the spindle or stud and a gear of 65 on the lead screw.

Treating Polished Iron or Steel.—Wash polished iron or steel that has become gray and lusterless, with a stiff brush and ammonia soapsuds. Rinse well and dry by heat if possible. Then apply a plentiful supply of sweet oil and dust thickly with powdered quicklime. Let the lime stay on two days, after which it should be cleaned off with a stiff brush. Polish with a softer brush and rub with cloths until the luster comes out. By leaving the lime on, iron and steel may be kept from rust almost indefinitely.

Speed of Grindstones.—To grind machinist's tools stones should have a speed of about 800 feet a minute at periphery, a 30 inch stone running about 100 revolutions a minute. In grinding carpenter's tools a speed of 600 feet a minute at periphery should be maintained, a 30 inch stone running 75 revolutions a minute.

Cleaning Brass Castings.—Brass castings that are greasy may be cleaned by boiling in lye or potash. The first pickle is composed of one quart of nitric acid, and six to eight quarts of water. After washing in clear warm or hot water the casting should be immersed in the second pickle, composed of one quart of sulphuric acid, two quarts of nitric acid and a few drops of muriatic acid.

Laying Out Work.—Use blue vitriol and water on the surface of steel or iron in laying out work. This will give a nice copperplate surface, so that all lines will show plainly. A little oil of vitriol will eat off oily surfaces and leave them nicely coppered.

Pipe Joint Cement.—Mix 10 parts of iron filings and three parts of chloride of lime to a paste by means of water. Apply to the joint and clamp. It will be solid in 12 hours.

Drilling.—Use kerosene to drill, ream or turn malleable iron, or to drill or turn aluminum. Turpentine should be used instead of oil for drilling hard steel, as it will cause drilling readily when the metal cannot be touched with oil. By using a combination of turpentine and camphor, glass may be drilled with a common drill. When the point of the drill comes through the hole should be worked with the end of a three-cornered file, having edges ground sharp. Use the corners of the file to scrape rather than as a reamer. Great care must be taken not to crack the glass or flake off pieces of it while finishing. The mixture should be used freely, both while drilling and scraping. It may be used as well to drill hard cast iron and tempered steel.

Body Polish.—A much recommended body polish is made by mixing the following ingredients:

Turpentine	1 gallon
Paraffine Oil	1 pint
Oil of Citronella	3½ ounces
Oil of Cedar	1½ ounces

Another scheme is to use a mixture of boiled linseed oil and turpentine, applying it sparingly and rubbing absolutely dry. The use of these polishes will restore even an old car to a degree of brightness that will please the owner. Floor wax is also used, as is furniture polish.

Care of Tops.—Mohair tops should be frequently dusted and brushed off. Pantasote tops and curtains are best cleaned with a soft brush dipped in water to which a little ammonia has been added. Afterwards rub dry. Never attempt to clean top and curtains with gasoline or kerosene. Do not fold the top until it has become thoroughly dry, because any moisture remaining in the folds is apt to cause mildew, besides making the top leaky and unsightly with spots. When a car is not used for some time, it is best to open the top, which keeps it well stretched and smooth.

Care of Leather Upholstery.—Do not use gasoline in cleaning leather upholstery. Plain water with a little ammonia will remove the dirt and a brisk rubbing with a clean woolen or flannel cloth

will do the rest. For still more careful treatment use a regular leather dressing.

Care of Cloth Upholstery.—Do not use an acid solution in cleaning cloth upholstery.

Cloth is not affected by climatic conditions and withstands both heat and cold, and having no oil in its make-up, does not pick up or hold dust readily. To remove ordinary dust, beat cushions and backs lightly with stick or carpet beater, then remove dust with whisk-broom or brush. Grease or oil may be removed by the application of a solution of luke warm water and Ivory soap applied with a woolen cloth. Any of the approved methods for cleaning woolen cloth may be used with success on this upholstery. Gasoline and benzine have a tendency to spread instead of removing the dirt. Their use is not recommended for this reason, although they work no injury to the fabric.

CHAPTER XIV

USEFUL TABLES FOR THE MECHANIC.

Mathematical Tables

Table of Inch Decimal Equivalents—Millimeter Decimal Equivalents—Metric Conversion Tables—General Formulæ in Mensuration—Diagonals of Hexagons and Squares—U. S. Measures and Weights—Trigonometrical Formulæ—Circumferences and Areas of Circles.

Mechanical Tables

S. A. E. Screw Standard—Standard Hexagon Bolts and Nuts—Machine Screw Table—Dimensions—Pipe Threads—S. A. E. Carburetor Fittings—Standards for Wire Gauges—Calculating Length of Chain—Table of Allowances for Grinding—Sizes of Drills to Use for Hand Taps—Twist Drill Gauge Sizes Speed of Drills—Figuring Emery Wheel Speeds—Pulley Sizes—Lathe Gearing for Cutting Threads—Allowances for Fits.

Miscellaneous Tables

Time Per Mile Expressed in Miles Per Hour—Comparative Scale, Fahrenheit and Centigrade Thermometers—Horsepower Chart—Compression Pressure—Approximate Horsepower of Four-Cycle Engines—Two-Cycle Engines—Indicated Horsepower—Weights of Metals—Weight of Steel Bars—Weight of Castings to That of Wood Patterns—Table of Gradients—Calculating Grade Percentages—Chart for Determining Speed of Car.

Those engaged in mechanical work cannot fail to appreciate the tables which follow, selected with care and with special reference to automobile repairing, machine work and allied industries. These have been compiled from standard authorities on mechanics, standards, metallurgy, automobile construction and design, mathematics, et cetera, and therefore can be divided into three general classes. Those dealing with arithmetic are in one group, those having to do with machine work are in another group, while the remainder deal with miscellaneous subjects. It is believed that the tabulation can be of value in many ways to the motorist as well as to the mechanic. While this data is available to all who can consult different standard works, it is believed that compilation in condensed form, as well as a rearrangement in some cases to simplify the matter, will make it

of real service to the laymen as well as the more expert machinist and repairman. Because of the number of authorities consulted and the many works from which the tables have been made, it is not possible to give individual acknowledgment, especially as many of the tabulations have long been public property and have been generally used by writers on mechanical subjects.

Table of Decimal Equivalents

8ths	$\frac{7}{32}$ = .21875	$\frac{19}{64}$ = .296875
$\frac{1}{8}$ = .125	$\frac{9}{32}$ = .28125	$\frac{21}{64}$ = .328125
$\frac{1}{4}$ = .250	$\frac{11}{32}$ = .34375	$\frac{23}{64}$ = .359375
$\frac{3}{8}$ = .375	$\frac{13}{32}$ = .40625	$\frac{25}{64}$ = .390625
$\frac{1}{2}$ = .500	$\frac{15}{32}$ = .46875	$\frac{27}{64}$ = .421875
$\frac{5}{8}$ = .625	$\frac{17}{32}$ = .53125	$\frac{29}{64}$ = .453125
$\frac{3}{4}$ = .750	$\frac{19}{32}$ = .59375	$\frac{31}{64}$ = .484375
$\frac{7}{8}$ = .875	$\frac{21}{32}$ = .65625	$\frac{33}{64}$ = .515625
	$\frac{23}{32}$ = .71875	$\frac{35}{64}$ = .546875
16ths	$\frac{25}{32}$ = .78125	$\frac{37}{64}$ = .578125
$\frac{1}{16}$ = .0625	$\frac{27}{32}$ = .84375	$\frac{39}{64}$ = .609375
$\frac{3}{16}$ = .1875	$\frac{29}{32}$ = .90625	$\frac{41}{64}$ = .640625
$\frac{5}{16}$ = .3125	$\frac{31}{32}$ = .96875	$\frac{43}{64}$ = .671875
$\frac{7}{16}$ = .4375		$\frac{45}{64}$ = .703125
$\frac{9}{16}$ = .5625	**64ths**	$\frac{47}{64}$ = .734375
$\frac{11}{16}$ = .6875	$\frac{1}{64}$ = .015625	$\frac{49}{64}$ = .765625
$\frac{13}{16}$ = .8125	$\frac{3}{64}$ = .046875	$\frac{51}{64}$ = .796875
$\frac{15}{16}$ = .9375	$\frac{5}{64}$ = .078125	$\frac{53}{64}$ = .828125
	$\frac{7}{64}$ = .109375	$\frac{55}{64}$ = .859375
32ds	$\frac{9}{64}$ = .140625	$\frac{57}{64}$ = .890625
$\frac{1}{32}$ = .03125	$\frac{11}{64}$ = .171875	$\frac{59}{64}$ = .921875
$\frac{3}{32}$ = .09375	$\frac{13}{64}$ = .203125	$\frac{61}{64}$ = .953125
$\frac{5}{32}$ = .15625	$\frac{15}{64}$ = .234375	$\frac{63}{64}$ = .984375
	$\frac{17}{64}$ = .265625	

Table of Decimal Equivalents of Millimeters and Fractions of Millimeters

Mm.	Inches	Mm.	Inches	Mm.	Inches
$\frac{1}{50}$ =	.00079	$\frac{26}{50}$ =	.02047	2 =	.07874
$\frac{2}{50}$ =	00157	$\frac{27}{50}$ =	.02126	3 =	.11811
$\frac{3}{50}$ =	.00236	$\frac{28}{50}$ =	02205	4 =	.15748
$\frac{4}{50}$ =	.00315	$\frac{29}{50}$ =	.02283	5 =	.19685
$\frac{5}{50}$ =	.00394	$\frac{30}{50}$ =	.02362	6 =	.23622
$\frac{6}{50}$ =	.00472	$\frac{31}{50}$ =	.02441	7 =	.27559
$\frac{7}{50}$ =	.00551	$\frac{32}{50}$ =	.02520	8 =	.31496
$\frac{8}{50}$ =	.00630	$\frac{33}{50}$ =	.02598	9 =	.35433
$\frac{9}{50}$ =	.00709	$\frac{34}{50}$ =	.02677	10 =	.39370
$\frac{10}{50}$ =	00787	$\frac{35}{50}$ =	.02756	11 =	.43307
$\frac{11}{50}$ =	.00866	$\frac{36}{50}$ =	.02835	12 =	.47244
$\frac{12}{50}$ =	.00945	$\frac{37}{50}$ =	.02913	13 =	.51181
$\frac{13}{50}$ =	.01024	$\frac{38}{50}$ =	.02992	14 =	.55118
$\frac{14}{50}$ =	.01102	$\frac{39}{50}$ =	.03071	15 =	.59055
$\frac{15}{50}$ =	.01181	$\frac{40}{50}$ =	.03150	16 =	.62992
$\frac{16}{50}$ =	.01260	$\frac{41}{50}$ =	.03228	17 =	.66929
$\frac{17}{50}$ =	.01339	$\frac{42}{50}$ =	.03307	18 =	.70866
$\frac{18}{50}$ =	01417	$\frac{43}{50}$ =	.03386	19 =	.74803
$\frac{19}{50}$ =	.01496	$\frac{44}{50}$ =	.03465	20 =	.78740
$\frac{20}{50}$ =	.01575	$\frac{45}{50}$ =	.03543	21 =	.82677
$\frac{21}{50}$ =	.01654	$\frac{46}{50}$ =	.03622	22 =	.86614
$\frac{22}{50}$ =	.01732	$\frac{47}{50}$ =	.03701	23 =	.90551
$\frac{23}{50}$ =	.01811	$\frac{48}{50}$ =	03780	24 =	.94488
$\frac{24}{50}$ =	.01890	$\frac{49}{50}$ =	.03858	25 =	.98425
$\frac{25}{50}$ =	.01969	1 =	.03937	26 =	1.02362

10 mm. = 1 Centimeter = 0.3937 inches.
10 cm. = 1 Decimer = 3.937 inches.
10 dm. = 1 Meter = 39.37 inches.
25.4 mm. = 1 English inch.

Metric System and English Equivalents.

The Metric System is based on the Meter which was designed to be one ten-millionth ($\frac{1}{10000000}$) part of the earth's meridian, passing through Dunkirk and Formentera. Later investigations, however, have shown that the Meter exceeds one ten-millionth part by almost one part in 6400. The value of the Meter, as authorized by the U. S. Government is 39.37 inches. The Metric system was legalized by the U. S. Government in 1866.

The three principal units are the meter, the unit of length, the liter, the unit of capacity, and the gram, the unit of weight. Multiples of these are obtained by prefixing the Greek words: deka (10), hekto (100), and kilo (1000). Divisions are obtained by prefixing the Latin words, deci ($\frac{1}{10}$), centi ($\frac{1}{100}$), and milli ($\frac{1}{1000}$). Abbreviations of the multiples begin with a capital letter, and of the divisions with a small letter, as in the following tables:

Measures of Length

10 millimeters (mm.)	= 1 centimeter (cm.)	= .3937 in.
10 centimeters	= 1 decimeter (dm.)	
10 decimeters	= 1 meter (m.)	= 3.28083 ft. = 39.37 ins.
10 meters	= 1 dekameter (Dm.)	
10 dekameters	= 1 hektometer (Hm.)	
10 hektometers	= 1 kilometer (Km.)	= 0.62137 mile
1 foot	= .3048 meter	
1 inch	= 25.4 millimeters	

Measures of Surface (not Land)

100 square millimeters (mm.^{2})	= 1 square centimeter (cm.^{2})	= 0.155 sq. in.
100 square centimeters	= 1 square decimeter (dm.^{2})	
100 square decimeters	= 1 square meter (m.^{2})	= 10.764 sq. ft.
1 square yard	= .836 square meter	
1 square foot	= .0929 square meter	
1 square inch	= 645.2 square millimeters	

Measures of Volume

1000 cubic millimeters (mm.^{3})	= 1 cubic centimeter (cm.^{3})	= .061 cu. in.
1000 cubic centimeters	= 1 cubic decimeter (dm.^{3}) = 1 liter	= 61.023 cu. ins.
1000 cubic decimeters	= 1 cubic meter (m.^{3})	= 35.314 cu. ft. = 264.2 gallons
1 cubic yard	= .7645 cubic meter	
1 cubic foot	= .02832 cubic meter	
1 cubic inch	= 16.387 cubic centimeters	

Measures of Capacity

10 milliliters (ml.)	= 1 centiliter (cl.)	
10 centiliters	= 1 deciliter (dl.)	
10 deciliters	= 1 liter (l.)	= 1.0567 qts. (U.S.) = 61.023 cu. ins.
10 liters	= 1 dekaliter (Dl.)	
10 dekaliters	= 1 hektoliter (Hl.)	
10 hektoliter	= 1 kiloliter (Kl.)	
1 gallon (U. S.)	= 3.785 liters	
1 gallon (British)	= 4.543 liters	

Measures of Weight

10 milligrams (mg.)	= 1 centigram (cg.)	
10 centigrams	= 1 decigram (dg.)	
10 decigrams	= 1 gram (g.)	= 15.432 grains
10 grams	= 1 dekagram (Dg.)	
10 dekagrams	= 1 hektogram (Hg.)	
10 hektograms	= 1 kilogram (Kg.)	= 2.2046 pounds
1000 kilograms	= 1 ton (T)	= .9842 ton of 2240 pounds

NOTE—The gram is the weight of one cubic centimeter of pure distilled water at a temperature of 39.2°F.; the kilogram is the weight of 1 liter of water; the ton is the weight of 1 cubic meter of water.

1 grain = .0648 gram	1 ounce (Avd.) = 28.35 grams
1 pound = .4536 kilograms	1 ton of 2240 pounds = 1.016 metric tons

General Formulæ.

Circumference = diameter x 3.1416, nearly; more accurately 3.141592

Approximations $\frac{22}{7} = 3.143$; $\frac{355}{113} = 3.141592$; $\frac{1}{3.141592} = .3183$

Diameter = circumference x .3183.

Diameter of circle x .88623 } = side of equal square.
Circumference of circle x .28209 }

Circumference of circle x 1.1284 = perimeter of equal square.

Diameter of circle x .7071 } = side of inscribed square.
Circumference of circle x .22508 }

Side of square x 1.4142 = diameter of circumscribed circle.
" " x 4.4428 = circum. " " "
" " x 1.1284 = diameter of equal circle.
" " x 3.5449 = circum. " " "

Perimeter of square x .88623 = circumference of equal circle.

Areas

Area of triangle = base x ½ perpendicular height.

Area of parallelogram = base x perpendicular height.

Area of trapezoid = half the sum of the parallel sides x perpendicular height.

Area of circle = diameter squared x .7854 nearly, more accurately .7853982.

Area of circle x .63662 = area of inscribed square.

Area of circular ring = sum of the two diameters x difference of the two diameters, and the product x .7854.

Area of parabola = base x ⅔ height.

Area of pyramid or cone = circumference or periphery of base x ½ slant height.

Area of ellipse = long diameter x short diameter x .7854.

Surfaces

Surface of cylinder = area of both ends + (length x circumference.)

Surface of sphere = diameter squared x 3.1416, or circumference x diameter.

Solid Contents

Contents of prism, right or oblique = area of base x perpendicular height.

Contents of cylinder = area of end x perpendicular height.

Contents of sphere = diameter cubed x .5236, or surface x ⅙ diam.

Contents of pyramid or cone = area of base x ⅓ perpendicular h'g't.

Diagonals of Hexagons and Squares

Across Flats	Across Corners Hexagon	Across Corners Squares	Across Flats	Across Corners Hexagon	Across Corners Squares	Across Flats	Across Corners Hexagon	Across Corners Squares
1/16	.072	.088	1 3/8	1.587	1.944	2 11/16	3.103	3.800
1/8	.144	.177	1 7/16	1.659	2.032	2 3/4	3.175	3.889
3/16	.216	.265	1 1/2	1.732	2.121	2 13/16	3.247	3.979
1/4	.288	.353	1 9/16	1.804	2.209	2 7/8	3.319	4.065
5/16	.360	.441	1 5/8	1.876	2.298	2 15/16	3 391	4.154
3/8	.432	.530	1 11/16	1.948	2.386	3	3.464	4.242
7/16	.505	.618	1 3/4	2.020	2.470	3 1/16	3.536	4.331
1/2	.577	.707	1 13/16	2.092	2.563	3 1/8	3.608	4.419
9/16	649	.795	1 7/8	2.165	2.651	3 3/16	3.680	4 507
5/8	.721	.883	1 15/16	2.237	2.740	3 1/4	3.752	4.596
11/16	.793	.972	2	2.309	2.828	3 5/16	3.824	4.684
3/4	.865	1.060	2 1/16	2.381	2.916	3 3/8	3.897	4.772
13/16	.938	1.149	2 1/8	2.453	3.005	3 1/2	4 041	4.949
7/8	1 010	1.237	2 3/16	2.525	3.093	3 5/8	4.185	5.126
15/16	1.082	1.325	2 1/4	2.598	3.182	3 3/4	4.330	5.303
1	1.155	1.414	2 5/16	2.670	3.270	3 7/8	4.474	5.480
1 1/16	1.226	1.502	2 3/8	2.742	3.358	4	4.618	5.656
1 1/8	1.299	1.591	2 7/16	2.814	3.447	4 1/8	4.763	5.833
1 3/16	1.371	1.679	2 1/2	2.886	3.535	4 1/4	4 904	6.010
1 1/4	1.443	1.767	2 9/16	2.958	3.623	4 3/8	5.051	6.187
1 5/16	1.515	1.856	2 5/8	3.031	3.712	4 1/2	5.196	6.368

Diagonal of hexagon equals 1.155 times distance across flats.
Diagonal of square equals 1.414 times distance across flats.

AREAS OF SMALL CIRCLES UP TO ONE INCH

DIA.	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
Inc.	AREAS									
.00	.0	.0078	.0314	.0706	.1256	.1963	.2827	.3848	.5026	.6362
.01	.000078	.0095	.03464	.0755	.132	.2043	.2922	.3959	.5153	.6504
.02	.00031	.0113	.038	.0804	.1385	.2124	.3014	.4071	.5281	.6648
.03	.0007	.0133	.0415	.0855	.1452	.2206	.3117	.4185	.5411	.6793
.04	.00125	.0154	.0452	.0908	.1520	.2290	.3217	.4301	.5542	.694
.05	.00196	.0177	.0491	.0962	.1590	.2376	.3318	.4418	.5674	.7088
.06	.00283	.0201	.0531	.1018	.1662	.2463	.3421	.4536	.5809	.7238
.07	.00385	.0227	.0572	.1075	.1735	.2552	.3526	.4657	.5945	.739
.08	.00503	.0255	.0616	.1134	.181	.2642	.3632	.4778	.6082	.7543
.09	.00638	.0283	.066	.1195	.1886	.2734	.3739	.4902	.6221	.7698

Across the top are the diameters of circles, and at the left are placed the increments increasing by .01 of an inch. Thus the area of a circle .56 of an inch in diameter, .2376 of a square inch, will be found under .5 and opposite .05.

CIRCUMFERENCES AND AREAS OF CIRCLES

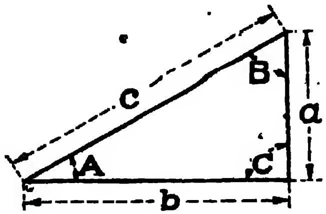
From 1 inch to 25 inches inclusive

Diam.	Circum.	Area
1	3.1416	.7854
1/16	3.3379	.8866
1/8	3.5343	.9940
3/16	3.7306	1.1075
1/4	3.9270	1.2272
5/16	4.1233	1.3530
3/8	4.3197	1.4849
7/16	4.5160	1.6230
1/2	4.7124	1.7671
9/16	4.9087	1.9175
5/8	5.1051	2.0739
11/16	5.3014	2.2365
3/4	5.4978	2.4053
13/16	5.6941	2.5802
7/8	5.8905	2.7612
15/16	6.0868	2.9483
2	6.2832	3.1416
1/16	6.4795	3.3410
1/8	6.6759	3.5466
3/16	6.8722	3.7583
1/4	7.0686	3.9761
5/16	7.2649	4.2000
3/8	7.4613	4.4301
7/16	7.6576	4.6664
1/2	7.8540	4.9087
9/16	8.0503	5.1572
5/8	8.2467	5.4119
11/16	8.4430	5.6727
3/4	8.6394	5.9396
13/16	8.8357	6.2126
7/8	9.0321	6.4918
15/16	9.2284	6.7771
3	9.4248	7.0686
1/16	9.6211	7.3662
1/8	9.8175	7.6699
3/16	10.014	7.9798
1/4	10.210	8.2958
5/16	10.407	8.6179
3/8	10.603	8.9462
7/16	10.799	9.2806
1/2	10.996	9.6211
9/16	11.192	9.9678
5/8	11.388	10.321
11/16	11.585	10.680
3/4	11.781	11.045
13/16	11.977	11.416
7/8	12.174	11.793
15/16	12.370	12.177

Diam.	Circum.	Area
4	12.566	12.566
1/16	12.763	12.962
1/8	12.959	13.364
3/16	13.155	13.772
1/4	13.352	14.186
5/16	13.548	14.607
3/8	13.744	15.033
7/16	13.941	15.466
1/2	14.137	15.904
9/16	14.334	16.349
5/8	14.530	16.800
11/16	14.726	17.257
3/4	14.923	17.728
13/16	15.119	18.190
7/8	15.315	18.665
15/16	15.512	19.147
5	15.708	19.635
1/16	15.904	20.129
1/8	16.101	20.629
3/16	16.297	21.135
1/4	16.493	21.648
5/16	16.690	22.166
3/8	16.886	22.691
7/16	17.082	23.221
1/2	17.279	23.758
9/16	17.475	24.301
5/8	17.671	24.850
11/16	17.868	25.406
3/4	18.064	25.967
13/16	18.261	26.535
7/8	18.457	27.109
15/16	18.653	27.688
6	18.850	28.274
1/8	19.242	29.465
1/4	19.635	30.680
3/8	20.028	31.919
1/2	20.420	33.183
5/8	20.813	34.472
3/4	21.206	35.785
7/8	21.598	37.122
7	21.991	38.485
1/8	22.384	39.871
1/4	22.776	41.282
3/8	23.169	42.718
1/2	23.562	44.197
5/8	23.955	45.664
3/4	24.347	47.173
7/8	24.740	48.707

Diam.	Circum.	Area
8	25.133	50.265
1/8	25.525	51.849
1/4	25.918	53.546
3/8	26.311	55.088
1/2	26.704	56.745
5/8	27.096	58.426
3/4	27.489	60.132
7/8	27.882	61.862
9	28.274	63.617
1/8	28.667	65.397
1/4	29.060	67.201
3/8	29.452	69.029
1/2	29.845	70.882
5/8	30.238	72.760
3/4	30.631	74.662
7/8	31.023	76.589
10	31.416	78.540
1/8	31.809	80.516
1/4	32.201	82.516
3/8	32.594	84.541
1/2	32.987	86.590
5/8	33.379	88.664
3/4	33.772	90.763
7/8	34.165	92.886
11	34.558	95.033
1/8	34.950	97.205
1/4	35.343	99.402
3/8	35.736	101.62
1/2	36.128	103.87
5/8	36.521	106.14
3/4	36.914	108.43
7/8	37.306	110.75
12	37.699	113.10
13	40.841	132.73
14	43.982	153.94
15	47.124	176.71
16	50.265	201.06
17	53.407	226.98
18	56.549	254.47
19	59.690	283.53
20	62.832	314.16
21	65.973	346.36
22	69.115	380.13
23	72.257	415.48
24	75.398	452.39
25	78.540	490.87

Trigonometrical Formulæ, Etc.



Geometrical Solution of Right-Angled Triangles

$c = \sqrt{a^2 + b^2}$

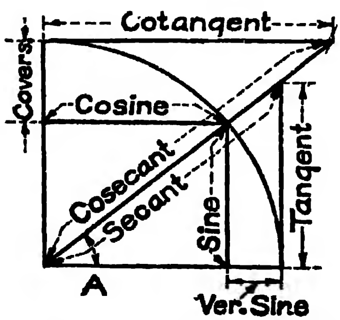
$b = \sqrt{c^2 - a^2}$

$a = \sqrt{c^2 - b^2}$

$\sin. A. = \dfrac{a}{c} = \dfrac{\text{opposite side}}{\text{hypotenuse}}$ $\qquad \cos. A. = \dfrac{b}{c} = \dfrac{\text{adjacent side}}{\text{hypotenuse}}$

$\tan. A. = \dfrac{a}{b} = \dfrac{\text{opposite side}}{\text{adjacent side}}$ $\qquad \cot. A. = \dfrac{b}{a} = \dfrac{\text{adjacent side}}{\text{opposite side}}$

$\sec. A. = \dfrac{c}{b} = \dfrac{\text{hypotenuse}}{\text{adjacent side}}$ $\qquad \text{cosec. } A. = \dfrac{c}{a} = \dfrac{\text{hypotenuse}}{\text{opposite side}}$



General Equivalents

The illustration shows the different trigonometrical expressions in terms of the angle A.

In the following formulæ the radius = 1.

Complement of an angle = its difference from 90°.
Supplement of an angle = its difference from 180°.

$$\text{Sin.} = \frac{1}{\text{cosec.}} = \frac{\text{cos.}}{\text{cot.}} = \sqrt{(1 - \text{cos.}^2)}$$

$$\text{Cos.} = \sqrt{(1 - \text{sin.}^2)} = \frac{\text{sin.}}{\text{tan.}} = \text{sin.} \times \text{cot.} = \frac{1}{\text{sec.}}$$

$$\text{Sec.} = \sqrt{\text{rad.}^2 + \text{tan.}^2} = \frac{1}{\text{cos.}} = \frac{\text{tan.}}{\text{sin.}} \qquad \text{Cosec} = \frac{1}{\text{sin.}}$$

$$\text{Tan.} = \frac{\text{sin.}}{\text{cos.}} = \frac{1}{\text{cot.}} \qquad \text{Cot.} = \frac{\text{cos.}}{\text{sin.}} = \frac{1}{\text{tan.}}$$

Versin. = rad.—cos. $\qquad$ Coversin. = rad.—sin.

$$\text{Rad.} = \text{tan.} \times \text{cot.} = \sqrt{\text{sin.}^2 + \text{cos.}^2}$$

U. S. Measures and Weights

DRY MEASURE.—U. S.

2 pints = 1 quart. 8 quarts = 1 peck. 4 pecks = 1 bushel.
The standard U. S. bushel is in cylinder form, 18½ inches diameter and 8 inches deep, and contains 2150.42 cubic inches.
A struck bushel = 2150.42 cubic inches, or 1.2445 cubic feet.
A heaped bushel = 1¼ struck bushels.

SHIPPING MEASURE.

100 cubic feet = 1 register ton.

40 cubic feet { 1 U. S. shipping ton. 31.16 Imperial bushels. 32.143 U. S. bushels.

42 cubic feet { 1 British shipping ton. 32.719 Imperial bushels. 33.75 U. S. bushels.

MEASURES OF WEIGHT.—Avoirdupois or Commercial Weight.

16 drachms, or 437.5 grains = 1 ounce, oz.
16 ounces, or 7,000 grains = 1 pound, lb.
28 pounds = 1 quarter, qr.
4 quarters = 1 hundred-weight, cwt. = 112 lbs.
20 hundred-weight = 1 ton of 2240 pounds, or long ton.
2000 pounds = 1 net, or short ton.
2204.6 pounds = 1 metric ton.
1 stone = 14 pounds. 1 quintal = 100 pounds.

TROY WEIGHT.

24 grains = 1 pennyweight, dwt.
20 pennyweights = 1 ounce, oz. = 480 grains.
12 ounces = 1 pound, lb. = 5760 grains.

APOTHECARIES' WEIGHT.

20 grains = 1 scruple.
3 scruple = 1 drachm = 60 grains.
8 drachms = 1 ounce = 480 grains.
12 ounces = 1 pound = 5760 grains.

CIRCULAR MEASURE.

60 seconds $''$ = 1 minute $'$.
60 minutes $'$ = 1 degree $^\circ$.
90 degrees = 1 quadrant.
360 degrees = 1 circumference.

TIME.

60 seconds = 1 minute.
60 minutes = 1 hour.
24 hours = 1 day.
7 days = 1 week.
365 days, 5 hours, 48 minutes, 48 seconds = 1 year.

BOARD MEASURE.

The number of feet, board measure (B. M.) = length in feet x breadth in feet x thickness in inches.

1 U. S. gallon=8.33 pounds. 1 cubic foot of water at 39.1°F=62.425 lbs.
1 English gallon=10 pounds. 1 cubic inch of water at 39.1°F=.036 lbs.
1 cubic foot of ice=57.2 pounds. 1 pound of water=27.72 cubic inches.
1 ton of water=35.90 cubic feet.

U. S. Measures and Weights

Continued

LONG MEASURE.—Measures of Length.

12 inches = 1 foot.
3 feet, or 36 inches = 1 yard.
5½ yards, or 16½ feet = 1 rod, pole, or perch.
40 rods, or 220 yards = 1 furlong.
8 furlongs, or 320 rods, or 1,760 yards or 5,280 feet = 1 mile.
3 miles = 1 league.

Additional Measures of Length.

1,000 mils = 1 inch. 4 inches = 1 hand. 9 inches = 1 span.
2½ feet = 1 military pace. 2 yards = 1 fathom.

SQUARE MEASURE.—Measures of Surface.

144 square inches, or 183.35 circular inches = 1 square foot.
9 square feet = 1 square yard.
30¼ square yards, or 272¼ square feet = 1 square rod, pole, or perch.
160 square rods = 1 acre.
640 acres = 1 square mile
An acre equals a square whose side is 208.71 feet.
A circular inch is the area of a circle 1 inch in diameter = 0.785398 sq. inches.
1 square inch = 1.2732 circular inches.
A circular mil is the area of a circle 1 mil or .001 in diameter. The mil is used in electrical calculations.

SOLID OR CUBIC MEASURES.—Measures of Volume.

1728 cubic inches = 1 cubic foot.
27 cubic feet = 1 cubic yard.
1 cord of wood = a pile, 4 x 4 x 8 feet = 128 cubic feet.
1 perch of masonry = 16½ x 1½ x 1 foot = 24¾ cubic feet.

LIQUID MEASURE.

4 gills = 1 pint.
2 pints = 1 quart.
4 quarts = 1 gallon { U. S. 231 cubic inches. English 277.274 cubic inches.
31½ gallons = 1 barrel.
42 gallons = 1 tierce.
2 barrels or 63 gallons = 1 hogshead.
84 gallons or 2 tierces = 1 puncheon.
2 hogshead or 126 gallons = 1 pipe or butt.
2 pipes or 3 puncheons = 1 tun.
7.4805 U. S. gallons = 1 cubic foot.
1 British Imperial gallon = 1.20032 U. S. gallons.

APOTHECARIES' FLUID MEASURE.

60 minims = 1 fluid drachm.
8 drachms, or 437½ grains, or 1,732 cubic inches = 1 fluid ounce.

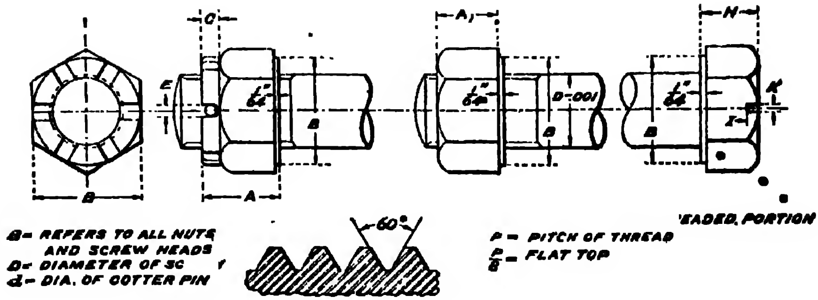
Water is at its greatest density at 39.2°F.

Sea water is 1.6 to 1.9 heavier than fresh water.

1 cubic inch of water makes approximately 1 cubic foot of steam at atmospheric pressure.

27222 cubic feet of steam at atmospheric pressure weighs 1 pound.

S. A. E. Screw Standard



D	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2
P	28	24	24	20	20	18	18	16	16	14	14	12	12	12	12
A	9/32	21/64	13/32	29/64	9/16	39/64	23/32	49/64	13/16	29/32	1	1 5/32	1 1/4	1 13/32	1 1/2
A₁	7/32	17/64	21/64	3/8	7/16	31/64	35/64	19/32	21/32	49/64	7/8	63/64	1 3/32	1 13/64	1 5/16
B	7/16	1/2	9/16	5/8	3/4	7/8	15/16	1	1 1/16	1 1/4	1 7/16	1 5/8	1 13/16	2	2 3/16
C	3/32	3/32	1/8	1/8	3/16	3/16	1/4	1/4	1/4	1/4	1/4	5/16	5/16	3/8	3/8
E	5/64	5/64	1/8	1/8	1/8	5/32	5/32	5/32	5/32	5/32	5/32	7/32	7/32	1/4	1/4
H	3/16	15/64	9/32	21/64	3/8	27/64	15/32	33/64	9/16	21/32	3/4	27/32	15/16	1 1/32	1 1/8
I	3/32	7/64	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	7/32	7/32	1/4	1/4
K	1/16	1/16	3/32	3/32	3/32	3/32	3/32	3/32	3/32	3/32	3/32	5/32	5/32	3/16	3/16
d	1/16	1/16	3/32	3/32	3/32	1/8	1/8	1/8	1/8	1/8	1/8	11/64	11/64	11/64	11/64

Calculations of Pulley Diameters and Revolutions

The Driving Pulley being called the Driver, and the Driven Pulley the Driven.

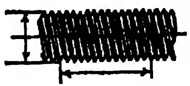
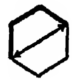
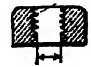
Diameter of Driver $= \dfrac{\text{Diameter of Driven} \times \text{Revolutions of Driven}}{\text{Revolutions of Driver}}$

Diameter of Driven $= \dfrac{\text{Diameter of Driver} \times \text{Revolutions of Driver}}{\text{Revolutions of Driven}}$

Revolutions of Driver $= \dfrac{\text{Diameter of Driven} \times \text{Revolutions of Driven}}{\text{Diameter of Driver}}$

Revolutions of Driven $= \dfrac{\text{Diameter of Driver} \times \text{Revolutions of Driver}}{\text{Diameter of Driven}}$

STANDARD HEXAGON BOLTS AND NUTS

										Safe Strain in lbs. — Iron at 50,000 lbs. per sq. in. — Factor of Safety 5
Diameter of Tap.	Threads per Inch.	Mill.	Across Corners.	Thickness U. S. Standard.	Depth of Thread.	Exact Size of Hole.	Tap Drill Used.	Width of Flat.	Area at Root of Thread.	
1/4	20	1/2	37/64	1/4	.0295	.1910	13/64	.0056	.0286	286
5/16	18	19/32	11/16	5/16	.0361	.2403	1/4	.0069	.0452	452
3/8	16	11/16	51/64	3/8	.0406	.2933	19/64	.0078	.0677	677
7/16	14	25/32	59/64	7/16	.0464	.3447	23/64	.0089	.0932	932
1/2	13	7/8	1 1/64	1/2	.0500	.4001	13/32	.0096	.1257	1257
9/16	12	31/32	1 1/8	9/16	.0542	.4542	15/32	.0104	.1620	1620
5/8	11	1 1/16	1 15/64	5/8	.0590	.5009	33/64	.0114	.2018	2018
3/4	10	1 1/4	1 29/64	3/4	.0650	.6201	5/8	.0125	.3020	3020
7/8	9	1 7/16	1 43/64	7/8	.0722	.7307	47/64	.0139	.4194	4194
1	8	1 5/8	1 7/8	1	.0812	.8376	27/32	.0156	.5509	5509
1 1/8	7	1 13/16	2 3/32	1 1/8	.0928	.9394	61/64	.0179	.6930	6930
1 1/4	7	2	2 5/16	1 1/4	.0928	1 0644	1 5/64	.0179	.8890	8890
1 3/8	6	2 3/16	2 17/32	1 3/8	.1083	1.1585	1 11/64	.0208	1 0540	10540
1 1/2	6	2 3/8	2 3/4	1 1/2	.1083	1 2835	1 19/64	.0208	1 2930	12935
1 3/4	5	2 3/4	3 3/16	1 3/4	.1300	1 4902	1 33/64	.0250	1 7440	17441
2	4 1/2	3 1/8	3 39/64	2	.1444	1 7113	1 23/32	.0278	2.3000	23000
2 1/4	4 1/2	3 1/2	4 3/64	2 1/4	.1444	1 9613	1 31/32	.0278	3 0210	30214
2 1/2	4	3 7/8	4 31/64	2 1/2	.1625	2.1752	2 3/16	.0313	3 7140	37149
2 3/4	4	4 1/4	4 59/64	2 3/4	.1625	2.4252	2 7/16	.0313	4.6180	46181
3	3 1/2	4 5/8	5 11/32	3	.1857	2.6288	2 41/64	.0357	5 4270	54275

GENERAL FORMULÆ, ETC.

1. Mill or distance across flats equals 1½ times the diameter of Tap, plus ⅛ inch.
2. Across corners or long diameter equals 1.155 times the mill. Table gives nearest 1/64 larger.
3. Exact depth of thread equals .65 times the pitch. Width of flat on thread equals ⅛ the pitch.
4. Exact size of hole U. S. Standard equals diameter Tap minus $\frac{1.299}{\text{No. threads per in.}}$ Tap Drill nearest 1/64 larger.
5. Bolt Heads same dimensions as Nuts.

MACHINE SCREW TABLE.

Screw Gauge Size.	Diameter in Decimals.	Approximate Diameter.	No. Threads per Inch.	Size of Tap Drill.
2	.0842	5/64	56	49
3	.0973	3/32	48	45
4	.1105	7/64	36	42
5	.1236	1/8	36	39
6	.1368	9/64	32	35
7	.1500	5/32	32	30
8	.1631	5/32	32	29
9	.1763	11/64	30	27
10	.1894	3/16	24	25
11	.2026	13/64	24	21
12	.2158	7/32	24	17
13	.2289	15/64	22	15
14	.2421	15/64	20	13
15	.2552	1/4	20	8
16	.2684	17/64	18	6
17	.2816	9/32	18	2
18	.2947	19/64	18	1
19	.3079	5/16	18	C
20	.3210	21/64	16	D
22	.3474	11/32	16	J
24	.3737	3/8	16	N
26	.4000	13/32	16	P
28	.4263	27/64	14	R
30	.4526	29/64	14	U

WEIGHTS OF METALS

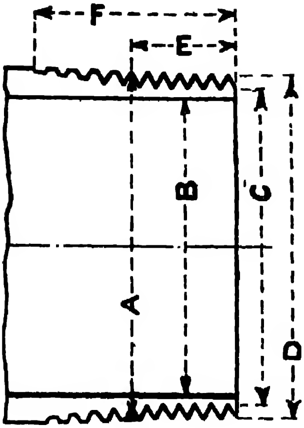
	Lbs. per Cu. Ft.	Lbs. per Cu. In.
Aluminum, cast	160	0926
Brass, cast	506.3	.293
Brass, sheet	528	3056
Babbitt metal	440.6	.255
Bronze, aluminum	471 2	2727
Bronze, phosphor	575.8	3332
Copper wire	555.1	3212
Cast iron	450.	2604
Wrought iron, bars	486.8	.2817
Steel, Bessemer	490.7	.284
Lead, cast	709.5	4106
Nickel	548.7	.3175
Tin	458.3	.2652
Zinc	436.5	.2526

WROUGHT IRON WELDED STEAM, GAS AND WATER PIPE. TABLE OF STANDARD DIMENSIONS.—NATIONAL TUBE WORKS CO.

Diameter.			Thickness.	Circumference.		Transverse Areas.			Length of Pipe per Sq. Foot of		Length of Pipe containing One Cubic Foot	Nominal Weight per Foot.	No. of Threads per Inch of Screw.
Nominal Internal.	Actual External	Actual Internal.		External.	Internal.	External.	Internal.	Metal.	External Surface	Internal Surface.			
Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Sq. Ins.	Sq. Ins.	Sq. Ins.	Ft	Ft	Ft	Lbs.	
1/8	.405	.27	.068	1.272	.848	.129	.0573	.0717	9.44	14.15	2513.	.241	27
1/4	.54	.364	.088	1.696	1.144	.229	.1041	.1249	7.075	10.49	1383.3	.42	18
3/8	.675	.494	.091	2.121	1.552	.358	.1917	.1663	5.657	7.73	751.2	.559	18
1/2	.84	.623	.109	2.639	1.957	.554	.3048	.2492	4.547	6.13	472.4	.837	14
3/4	1.05	.824	.113	3.299	2.589	.866	.5333	.3327	3.637	4.635	270.	1.115	14
1	1.315	1.048	.134	4.131	3.292	1.358	.8628	.4954	2.904	3.645	166.9	1.668	11 1/2
1 1/4	1.66	1.38	.14	5.215	4.335	2.164	1.496	.668	2.301	2.768	96.25	2.244	11 1/2
1 1/2	1.9	1.611	.145	5.969	5.061	2.835	2.038	.797	2.01	2.371	70.66	3.678	11 1/2
2	2.375	2.067	.154	7.461	6.494	4.43	3.356	1.074	1.608	1.848	42.91	4.609	11 1/2
2 1/2	2.875	2.468	.204	9.032	7.753	6.492	4.784	1.708	1.328	1.547	30.1	5.739	8
3	3.5	3.067	.217	10.996	9.636	9.621	7.388	2.243	1.091	1.245	19.5	7.536	8
3 1/2	4.	3.548	.226	12.566	11.146	12.566	9.887	2.679	.955	1.077	14.57	9.001	8
4	4.5	4.026	.237	14.137	12.648	15.904	12.73	3.174	.849	.949	11.31	10.665	8
4 1/2	5.	4.508	.246	15.708	14.162	19.635	15.961	3.674	.764	.848	9.02	12.34	8
5	5.563	5.045	.259	17.477	15.849	24.306	19.99	4.316	.687	.757	7.2	14.502	8
6	6.625	6.065	.28	20.813	19.054	34.472	28.888	5.584	.577	.63	4.98	18.762	8
7	7.625	7.023	.301	23.955	22.063	45.664	38.738	6.926	.501	.544	3.72	23.271	8
8	8.625	7.982	.322	27.096	25.076	58.426	50.04	8.386	.443	.478	2.88	28.177	8
9	9.625	8.937	.344	30.238	28.076	72.76	62.73	10.03	.397	.427	2.29	33.701	8
10	10.75	10.019	.366	33.772	31.477	90.763	78.839	11.924	.355	.382	1.82	40.065	8
11	12.	11.25	.375	37.699	35.343	113.098	99.402	13.696	.318	.339	1.456	45.95	8
12	12.75	12.	.375	40.055	37.7	127.677	113.098	14.579	.299	.319	1.27	48.985	8

Wrought Iron Welded Pipe and Pipe Threads

Briggs' Standard



A—Outside diameter of perfect thread or actual outside diameter of pipe.

B—Inside diameter of pipe.

C—Root diameter of thread at end.

D—Outside diameter of thread at end.

E—Length of perfect thread = $P(4.8+0.8A)$

F—Total length of thread or length of taper at top.

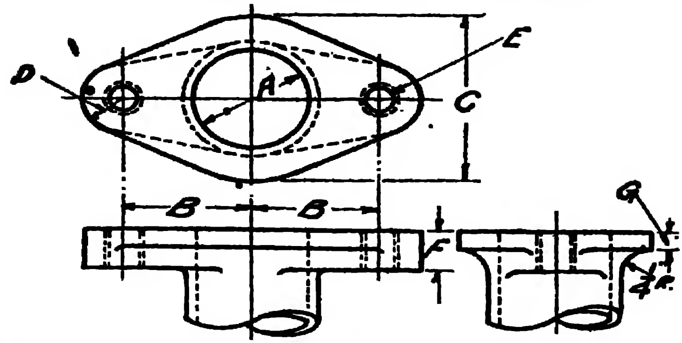
N—Number of threads per inch.

P—Pitch of thread $=\frac{1}{N}$

Taper of thread, ¾″ per foot or 1 in 32 to axis of pipe.

Diam. of Tube in Ins.			Nominal Weight per ft. lbs.	Internal Area sq. ins	Pipe Thread Dimensions					Size of Tap Drill
Nominal Inside	Actual Inside B	Actual Outside A			C	D	E	F	N	
⅛	0.270	0.405	.24	.057	.334	.393	.19	.41	27	11/32
¼	0.364	0.540	.42	.104	.433	.522	.29	.62	18	7/16
⅜	0.494	0.675	.55	.192	.567	.656	.30	.63	18	19/32
½	0.623	0.840	.83	.305	.702	.816	.39	.82	14	23/32
¾	0.824	1.050	1.11	.533	.911	1.025	.40	.83	14	15/16
1	1.048	1.315	1.66	.863	1.144	1.283	.51	1.03	11½	1 3/16
1¼	1.380	1.660	2.24	1.496	1.488	1.627	.54	1.06	11½	1 15/32
1½	1.610	1.900	2.67	2.038	1.727	1.866	.55	1.07	11½	1 23/32
2	2.067	2.375	3.60	3.355	2.200	2.339	.58	1.10	11½	2¼
2½	2.468	2.875	5.73	4.783	2.618	2.818	.89	1.64	8	2 11/16
3	3.067	3.500	7.53	7.388	3.243	3.443	.95	1.70	8	3 5/16
3½	3.548	4.000	9.00	9.887	3.738	3.938	1.00	1.75	8	3 13/16
4	4.026	4.500	10.66	12.73	4.233	4.443	1.05	1.80	8	4 5/16
4½	4.508	5.000	12.34	15.93	4.733	4.933	1.10	1.85	8	4 13/16
5	5.045	5.563	14.50	19.99	5.289	5.489	1.16	1.91	8	5 11/32
6	6.065	6.625	18.76	28.88	6.347	6.547	1.26	2.01	8	6 13/32
7	7.023	7.625	23.27	38.73	7.340	7.540	1.36	2.11	8	....
8	7.982	8.625	28.17	50.03	8.332	8.532	1.46	2.21	8	....
9	9.000	9.625	33.70	63.63	9.324	9.524	1.56	2.31	8	....
10	10.019	10.750	40.06	78.83	10.44	10.64	1.67	2.42	8	....

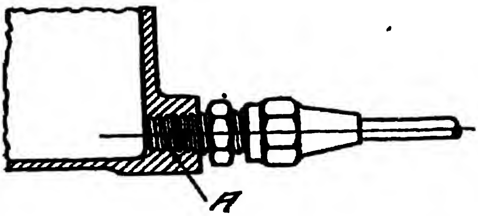
CARBURETER FITTINGS—Flanges



Carbureter Size	A	B	C	D	E*	F	G
3/4	15/16"	1 1/16"	1 5/8"	11/32"	5/16"x18 thr.	3/8"	1/8"
7/8	1 1/16"	1 1/8"	1 3/4"	11/32"	5/16"x18 thr.	3/8"	1/8"
✓1	1 3/16"	1 3/16"	1 7/8"	11/32"	5/16"x18 thr.	13/32"	5/32"
1 1/4	1 7/16"	1 11/32"	2 1/16"	13/32"	3/8"x16 thr.	13/32"	5/32"
1 1/2	1 11/16"	1 15/32"	2 1/4"	13/32"	3/8"x16 thr.	15/32"	3/16"
1 3/4	1 15/16"	1 21/32"	2 11/16"	15/32"	7/16"x14 thr.	[illegible]	7/32"
2	2 3/16"	1 25/32"	3 1/8"	15/32"	7/16"x14 thr.	[illegible]	7/32"

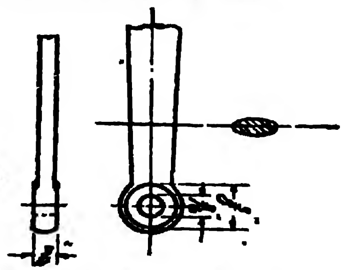
*U. S. Standard thread.
All dimensions in inches.

GASOLINE PIPE SIZES

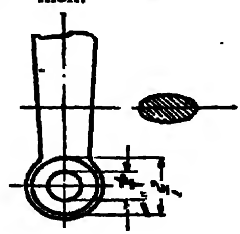


Carbureter Size	A, Briggs Standard. Pipe Thread
3/4"	1/8"
7/8"	1/8"
1"	1/8"
1 1/4"	1/4"
1 1/2"	1/4"
1 3/4"	1/4"
2"	1/4"

THROTTLE LEVERS



5/16" Rod end for carbureters up to 1 inch.

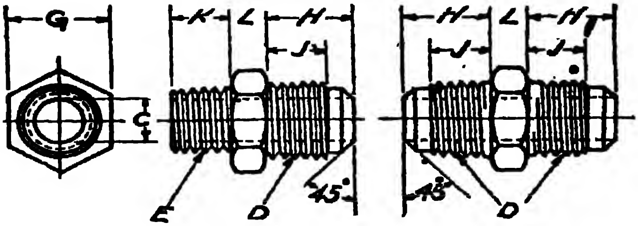


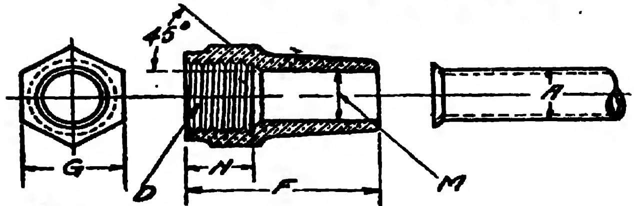
1/4" Rod end for carbureters of 1 1/4 to 2 inches inclusive

Recommended by the Standards Committee and accepted by the Society of Automobile Engineers, June, 1912.

CARBURETER FITTINGS

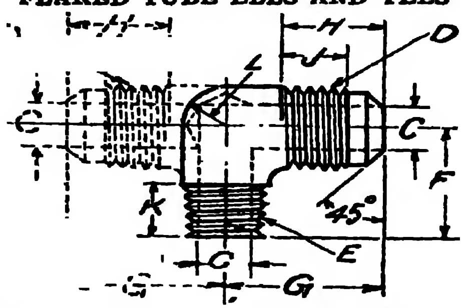
Flared Tube Unions





A	Pipe diameter..........	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
C	Bore, male part..........	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
D	S. A. E. thread..........	7/16x20 thr.	1/2x20 thr.	5/8x18 thr.	11/16x16 thr.	3/4x16 thr.
E	Pipe thread..........	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
F	....	[illegible]	1 1/8	1 3/16	[illegible]	[illegible]
G	....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
H	....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
J	Thread only..........	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
K	Thread only..........	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
L	....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
M	Bore, female part..........	0.255–0.257	0.317–0.319	0.380–0.382	0.442–0.444	0.505–0.507
N	....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

FLARED TUBE ELLS AND TEES



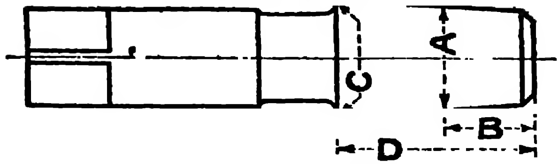
A	Tube diameter..........	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
C	Drill diameter..........	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
D	S. A. E. thread..........	7/16x20	1/2x20	5/8x18	11/16x16	3/4x16
E	Briggs std. pipe thread.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
F	Center to face..........	[illegible]	[illegible]	[illegible]	[illegible]	1
G	Center to face..........	[illegible]	[illegible]	1	1 1/8	1 3/16
H	....	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
J	Thread only..........	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
K	Thread only..........	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
L	Radius..........	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

All dimensions on this sheet in inch measure.

Recommended by the Standards Committee and accepted by the Society of Automobile Engineers, June, 1912.

Pipe Tap Dimensions

Briggs' Standard

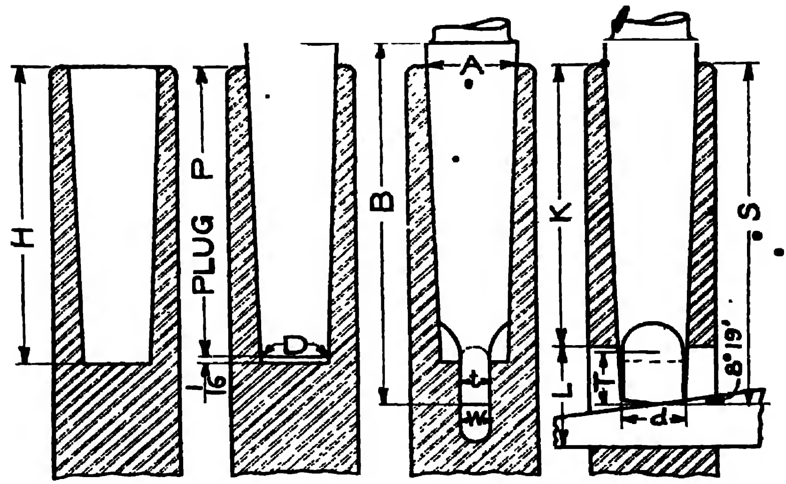


Nom. Pipe Size	Diam. at Size Line A	Dist. End to Size Line B	Diam. at large End C	Length of Thread D	Nom. Pipe Size	Diam. at Size Line A	Dist. End to Size Line B	Diam. at large End C	Length of Thread D
1/8	0.405	15/64	0.443	1	3	3.500	1 9/16	3.605	3 1/4
1/4	0.540	9/16	0.575	1 1/8	3 1/2	4.000	1 5/8	4.125	3 3/8
3/8	0.675	9/16	0.718	1 1/4	4	4.500	1 11/16	4.629	3 1/2
1/2	0.840	3/4	0.887	1 1/2	4 1/2	5.000	1 3/4	5.125	3 3/4
3/4	1.050	3/4	1.104	1 5/8	5	5.563	2	5.687	4
1	1.315	15/16	1.366	1 3/4	6	6.625	2 1/4	6.766	4 1/8
1 1/4	1.660	31/32	1.717	1 7/8	7	7.625	2 5/16	7.773	4 1/4
1 1/2	1.900	1	1.963	2	8	8.625	2 3/8	8.773	4 1/2
2	2.375	1	2.453	2 1/4	9	9.625	2 1/2	9.781	5
2 1/2	2.875	1 1/2	2.961	2 3/8	10	10.750	2 1/2	10.906	5

Whitworth's Gas and Water Piping

Diam. of Piping		Diam. at Bottom of Thread	No. of Thr'ds per in.	Size of Tap Drill	Diam. of Piping		Diam. at Bottom of Thread	No. of Thr'ds per in.	Size of Tap Drill
Internal	External				Internal	External			
1/8	.3825	.3367	28	11/32	1 7/8	2.245	2.1285	11	2 5/32
1/4	.518	.4506	19	15/32	2	2.347	2.2305	11	2 17/64
3/8	.6563	.5889	19	19/32	2 1/8	2.467	2.3505	11	2 13/32
1/2	.8257	.7342	14	47/64	2 1/4	2.5875	2.4710	11	2 31/64
5/8	.9022	.8107	14	53/64	2 3/8	2.794	2.6775	11	2 11/16
3/4	1.041	.9495	14	31/32	2 1/2	3.0013	2.8848	11	2 57/64
7/8	1.189	1.0975	14	1 1/8	2 5/8	3.124	3.0075	11	3 1/32
1	1.309	1.1925	11	1 7/32	2 3/4	3.247	3.1305	11	3 11/64
1 1/8	1.492	1.3755	11	1 13/32	2 7/8	3.367	3.2505	11	3 9/32
1 1/4	1.650	1.5335	11	1 9/16	3	3.485	3.3685	11	3 13/32
1 3/8	1.745	1.6285	11	1 21/32	3 1/4	3.6985	3.5820	11	3 5/8
1 1/2	1.8825	1.7660	11	1 51/64	3 1/2	3.912	3.7955	11	3 53/64
1 5/8	2.021	1.9045	11	1 15/16	3 3/4	4.1255	4.0090	11	4 1/32
1 3/4	2.047	1.9305	11	1 31/32	4	4.339	4.2225	11	4 17/64

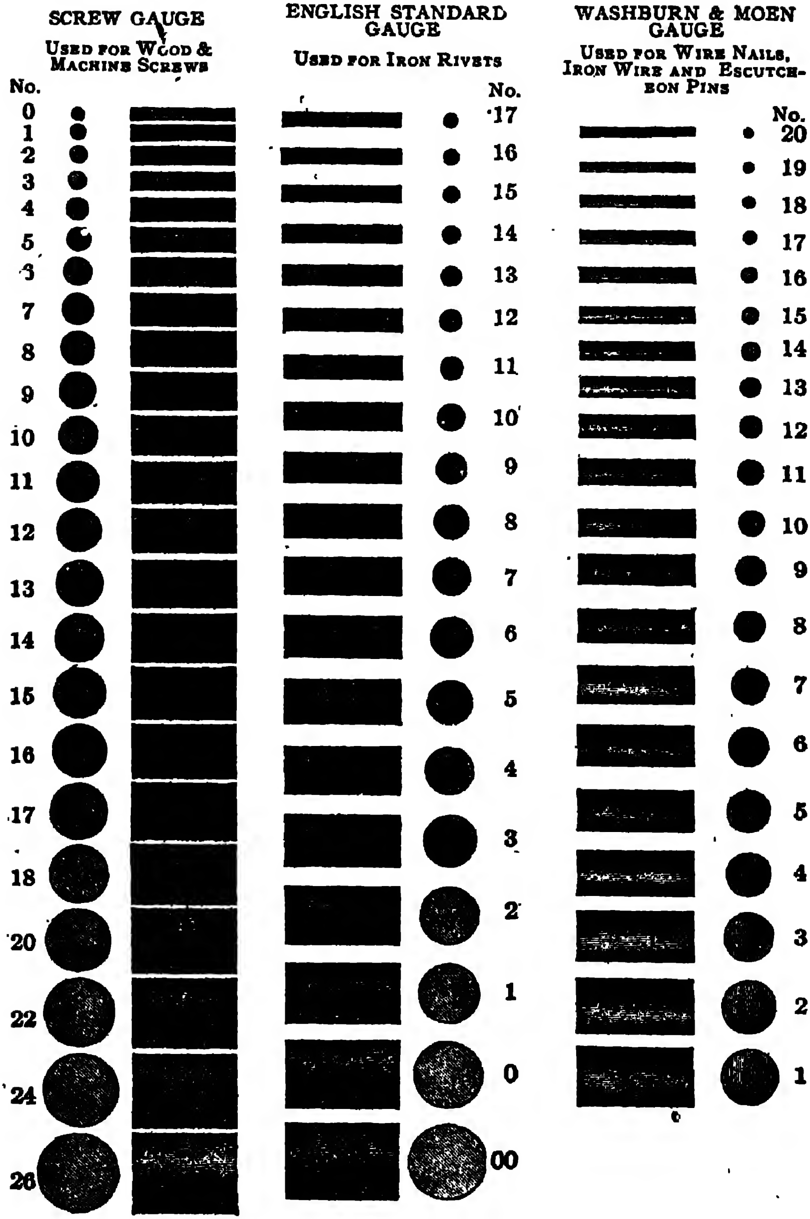
Morse Tapers



Number of Taper		No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
Diameter of Plug at Small End	D	.369	.572	.778	1.02	1.475	2.116
Standard Plug Depth	P	$2\frac{1}{8}$	$2\frac{9}{16}$	$3\frac{3}{16}$	$4\frac{1}{16}$	$5\frac{3}{16}$	$7\frac{1}{4}$
Depth of Hole	H	$2\frac{3}{16}$	$2\frac{5}{8}$	$3\frac{1}{4}$	$4\frac{1}{8}$	$5\frac{1}{4}$	$7\frac{3}{8}$
End of Socket to Keyway	K	$2\frac{1}{16}$	$2\frac{1}{2}$	$3\frac{1}{16}$	$3\frac{7}{8}$	$4\frac{15}{16}$	7
Length of Keyway	L	$\frac{3}{4}$	$\frac{7}{8}$	$1\frac{1}{16}$	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$
Width of Keyway	W	.213	.265	.330	.490	.650	.780
Length of Tongue	T	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	1
Diameter of Shank at Small End	d	.353	.553	.753	.991	1.440	2.064
Thickness of Tongue	t	$\frac{13}{64}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{15}{32}$	$\frac{5}{8}$	$\frac{3}{4}$
Shank Depth	S	$2\frac{7}{16}$	$2\frac{15}{16}$	$3\frac{11}{16}$	$4\frac{5}{8}$	$5\frac{7}{8}$	$8\frac{1}{4}$
Whole Length of Shank	B	$2\frac{11}{16}$	$3\frac{3}{16}$	$3\frac{15}{16}$	$5\frac{1}{8}$	$6\frac{1}{8}$	$8\frac{1}{4}$
Diameter at End of Socket	A	.475	.700	.938	1.231	1.748	2.494
Taper per Foot		.600	.602	.602	.623	.630	.626
Smallest Drill Using Each Taper		$\frac{1}{8}$	$\frac{19}{32}$	$\frac{59}{64}$	$1\frac{17}{64}$	$2\frac{1}{64}$	$3\frac{1}{16}$
Largest Drill Using Each Taper		$\frac{37}{64}$	$\frac{29}{32}$	$1\frac{1}{4}$	2	3	6

Taper of key = $1\frac{1}{4}$" in 12".

COMPARISON OF GAUGES



DIFFERENT STANDARDS FOR WIRE GAUGES

IN USE IN THE UNITED STATES

Dimensions of Sizes in Decimal Parts of an Inch

Number of Wire Gauge	American or Brown & Sharpe	Birmingham or English Standard	Washburn & Moen Mfg Co. Worcester, Mass.	Imperial Wire Gauge	Stubs' Steel Wire	Number of Wire Gauge
000000	....	....	.....	.464	....	000000
00000	....	....	.....	.432	....	00000
0000	.46	.454	.3938	.400	....	0000
000	.40964	.425	.3625	.372	....	000
00	.3648	.38	.3310	.348	....	00
0	.32486	.34	.3065	.324	....	0
1	.2893	.3	.2830	.300	.227	1
2	.25763	.284	.2625	.276	.219	2
3	.22942	.259	.2437	.252	.212	3
4	.20431	.238	.2253	.232	.207	4
5	.18194	.22	.2070	.212	.204	5
6	.16202	.203	.1920	.192	.201	6
7	.14428	.18	.1770	.176	.199	7
8	.12849	.165	.1620	.160	.197	8
9	.11443	.148	.1483	.144	.194	9
10	.10189	.134	.1350	.128	.191	10
11	.090742	.12	.1205	.116	.188	11
12	.080808	.109	.1055	.104	.185	12
13	.071961	.095	.0915	.092	.182	13
14	.064084	.083	.0800	.080	.180	14
15	.057068	.072	.0720	.072	.178	15
16	.05082	.065	.0625	.064	.175	16
17	.045257	.058	.0540	.056	.172	17
18	.040303	.049	.0475	.048	.168	18
19	.03589	.042	.0410	.040	.164	19
20	.031961	.035	.0348	.036	.161	20
21	.028462	.032	.03175	.032	.157	21
22	.025347	.028	.0286	.028	.155	22
23	.022571	.025	.0258	.024	.153	23
24	.0201	.022	.0230	.022	.151	24
25	.0179	.02	.0204	.020	.148	25
26	.01594	.018	.0181	.018	.146	26
27	.014195	.016	.0173	.0164	.143	27
28	.012641	.014	.0162	.0149	.139	28
29	.011257	.013	.0150	.0136	.134	29
30	.010025	.012	.0140	.0124	.127	30
31	.008928	.01	.0132	.0116	.120	31
32	.00795	.009	.0128	.0108	.115	32
33	.00708	.008	.0118	.0100	.112	33
34	.006304	.007	.0104	.0092	.110	34
35	.005614	.005	.0095	.0084	.108	35
36	.005	.004	.0090	.0076	.106	36
37	.004453	....	.....	.0068	.103	37
38	.003965	....	.....	.0060	.101	38
39	.003531	....	.....	.0052	.099	39
40	.003144	....	.....	.0048	.097	40

DIFFERENT STANDARDS FOR WIRE GAUGES

IN USE IN THE UNITED STATES

Dimensions of Sizes in Decimal Parts of an Inch

Number of Wire Gauge	H., S. & Co. "F. & G." Steel Music Wire Gauge	Screw Gauge	London Gauge	U. S. Standard for Plate	Number of Wire Gauge
000000	......	......	......	.46875	000000
00000	......	......	......	.4375	00000
0000	......	......	.454	.40625	0000
000	.....	......	.425	.375	000
00	.0087	......	.380	.34375	00
0	.0093	.0578	.340	.3125	0
1	.0098	.0710	.300	.28125	1
2	.0106	.0842	.284	.265625	2
3	.0114	.0973	.259	.25	3
4	.0122	.1105	.238	.234375	4
5	.0138	.1236	.220	.21875	5
6	.0157	.1368	.203	.203125	6
7	.0177	.1500	.180	.1875	7
8	.0197	.1631	.165	.171875	8
9	.0216	.1763	.148	.15625	9
10	.0236	.1894	.134	.140625	10
11	.0260	.2026	.120	.125	11
12	.0283	.2158	.109	.109375	12
13	.0303	.2289	.095	.09375	13
14	.0323	.2421	.083	.078125	14
15	.0342	.2552	.072	.0703125	15
16	.0362	.2684	.065	.0625	16
17	.0382	.2816	.058	.05625	17
18	.04	.2947	.049	.05	18
19	.042	......	.040	.04375	19
20	.044	.3210	.035	.0375	20
21	.046	......	.0315	.034375	21
22	.048	.3474	.0295	.03125	22
23	.051	......	.027	.028125	23
24	.055	.3737	.025	.025	24
25	.059	......	.023	.021875	25
26	.063	.4000	.0205	.01875	26
27	.067	......	.01875	.0171875	27
28	.071	.4263	.0165	.015625	28
29	.074	......	.155	.0140625	29
30	.078	.4520	.01375	.0125	30
31	.082	......	.01225	.0109375	31
32	.086	......	.01125	.01015625	32
33	......	......	.01025	.009375	33
34	......	......	.0095	.00859375	34
35	......	......	.009	.0078125	35
36	......	......	.0075	.00703125	36
37	......	......	.0065	.006640625	37
38	......	......	.00575	.00625	38
39	......	......	.005	....	39
40	......	......	.0045	....	40

Twist Drill Gauge Sizes

No. Drill	Decimal Sizes	No. Drill	Decimal Sizes
1	.2280	31	.1200
2	.2210	32	.1160
3	.2130	33	.1130
4	.2090	34	.1110
5	.2055	35	.1100
6	.2040	36	.1065
7	.2010	37	.1040
8	.1990	38	.1015
9	.1960	39	.0995
10	.1935	40	.0980
11	.1910	41	.0960
12	.1890	42	.0935
13	.1850	43	.0890
14	.1820	44	.0860
15	.1800	45	.0820
16	.1770	46	.0810
17	.1730	47	.0785
18	.1695	48	.0760
19	.1660	49	.0730
20	.1610	50	.0700
21	.1590	51	.0670
22	.1570	52	.0635
23	.1540	53	.0595
24	.1520	54	.0550
25	.1495	55	.0520
26	.1470	56	.0465
27	.1440	57	.0430
28	.1405	58	.0420
29	.1360	59	.0410
30	.1285	60	.0400

Letter Sizes

A .234	H .266	O .316	U .368
B .238	I .272	P .323	V .377
C .242	J .277	Q .332	W .386
D .246	K .281	R .339	X .397
E .250	L .290	S .348	Y .404
F .257	M .295	T .358	Z .413
G .261	N .302		

Sizes of Drills to be used with V Thread, Hand and Nut Taps

Size of Tap	Size of Drill	Size of Tap	Size of Drill
$\frac{1}{4}$ X 20	$\frac{3}{16}$	$\frac{15}{16}$ X 9	$\frac{25}{32}$
$\frac{5}{16}$ X 18	$\frac{15}{64}$	1 X 8	$\frac{53}{64}$
$\frac{3}{8}$ X 16	$\frac{19}{64}$	$1\frac{1}{8}$ X 7	$\frac{15}{16}$
$\frac{7}{16}$ X 14	$\frac{11}{32}$	$1\frac{1}{4}$ X 7	$1\frac{1}{16}$
$\frac{1}{2}$ X 12	$\frac{25}{64}$	$1\frac{3}{8}$ X 6	$1\frac{9}{64}$
$\frac{9}{16}$ X 12	$\frac{29}{64}$	$1\frac{1}{2}$ X 6	$1\frac{17}{64}$
$\frac{5}{8}$ X 11	$\frac{1}{2}$	$1\frac{5}{8}$ X 5	$1\frac{11}{32}$
$\frac{11}{16}$ X 11	$\frac{9}{16}$	$1\frac{3}{4}$ X 5	$1\frac{15}{32}$
$\frac{3}{4}$ X 10	$\frac{39}{64}$	$1\frac{7}{8}$ X $4\frac{1}{2}$	$1\frac{37}{64}$
$\frac{13}{16}$ X 10	$\frac{43}{64}$	2 X $4\frac{1}{2}$	$1\frac{11}{16}$
$\frac{7}{8}$ X 9	$\frac{23}{32}$		

Formula for finding proper size of Drills for all pitches of V Threads:

Example: $\frac{3}{4}$ X 10 Tap.

1.400 ÷ 10 = .140—.750 = .610, size of Root Diameter, or size of Drill to be used.

Note.—For U. S. Standard Threads use same formula except use 1.3 of pitch instead of 1.4.

TABLE OF EMERY WHEEL SPEEDS.

Diam. Wheel	Rev. per Minute for Surface Speed of 4,000 Feet.	Rev. per Minute for Surface Speed of 5,000 Feet.	Rev. per Minute for Surface Speed of 6,000 Feet.
1 inch.	15,279	19,099	22,918
2 "	7,639	9,549	11,459
3 "	5,093	6,366	7,639
4 "	3,820	4,775	5,730
5 "	3,056	3,820	4,584
6 "	2,546	3,183	3,820
7 "	2,183	2,728	3,274
8 "	1,910	2,387	2,865
10 "	1,528	1,910	2,292
12 "	1,273	1,592	1,910
14 "	1,091	1,364	1,637
16 "	955	1,194	1,432
18 "	849	1,061	1,273
20 "	764	955	1,146
22 "	694	868	1,042
24 "	637	796	955
26 "	586	743	879
28 "	546	683	819
30 "	509	637	764
32 "	477	596	716
34 "	449	561	674
36 "	424	531	637
38 "	402	503	603
40 "	382	478	573
42 "	364	455	546
44 "	347	434	521
46 "	332	415	498
48 "	318	397	477
50 "	306	383	459
52 "	294	369	441
54 "	283	354	425
56 "	273	341	410
58 "	264	330	396
60 "	255	319	382

THE SPEED OF DRILLS.

Cleveland Twist Drill Co.

Diam. of Drill.	Speed for Soft Steel.	Speed for Iron.	Speed for Brass.	Diam. of Drill.	Speed for Soft Steel.	Speed for Iron.	Speed for Brass.
1/16	1,824	2,128	3,648	1 1/16	108	125	215
1/8	912	1,064	1,824	1 1/8	102	118	203
3/16	608	710	1,216	1 3/16	96	112	192
1/4	456	532	912	1 1/4	91	106	182
5/16	365	425	730	1 5/16	87	101	174
3/8	304	355	608	1 3/8	83	97	165
7/16	260	304	520	1 7/16	80	93	159
1/2	228	266	456	1 1/2	76	89	152
9/16	203	236	405	1 9/16	73	85	145
5/8	182	213	365	1 5/8	70	82	140
11/16	166	194	332	1 11/16	68	79	135
3/4	152	177	304	1 3/4	65	76	130
13/16	140	164	280	1 13/16	63	73	125
7/8	130	152	260	1 7/8	60	71	122
15/16	122	142	243	1 15/16	59	69	118
1	114	133	228	2	57	67	114

Table of Allowances for Grinding

Length / Diam.	3″	6″	9″	12″	15″	18″	24″	30″	36″	42″	48″
½	.010	.010	.010	.010	.015	.015	.015	.020	.020	.020	.020
¾	.010	.010	.010	.010	.015	.015	.015	.020	.020	.020	.020
1	.010	.010	.010	.015	.015	.015	.015	.020	020	.020	.020
1¼	.010	.010	.015	.015	.015	.015	.015	.020	020	.020	.020
1½	.010	.015	.015	.015	.015	.015	.020	.020	020	.020	.020
2	.015	.015	.015	.015	.015	.020	.020	020	.020	.020	.025
2¼	.015	.015	015	.015	.020	.020	.020	.020	.020	.025	.025
2½	.015	.015	.015	.020	.020	.020	.020	020	.025	.025	.025
3	.015	.015	.020	.020	.020	.020	.020	.025	.025	.025	.025
3½	.015	.020	.020	.020	.020	.020	.025	.025	.025	.025	.025
4	.020	.020	.020	.020	.020	.025	.025	.025	.025	025	.030
4½	.020	.020	.020	.020	.025	.025	.025	.025	.025	.030	.030
5	.020	.020	.020	.025	.025	.025	.025	.025	.030	.030	.030
6	.020	.020	.025	.025	.025	.025	.025	.030	.030	.030	.030
7	.020	.025	.025	.025	.025	.025	.030	.030	.030	.030	.030
8	.025	.025	.025	.025	.025	.030	.030	.030	.030	.030	.030
9	.025	.025	.025	.025	.030	.030	.030	.030	.030	.030	.030
10	.025	.025	.025	.030	.030	.030	.030	.030	.030	.030	030
11	.025	.025	.030	.030	.030	.030	.030	.030	.030	.030	030
12	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030

WEIGHT IN POUNDS OF A LINEAL FOOT OF ROUND, SQUARE AND OCTAGON STEEL

Size in Inches	Round	Octagon	Square	Size in Inches	Round	Octagon	Square
1/16	.010	.011	.013	2 1/2	16.79	17.71	21.37
1/8	.042	.044	.053	2 5/8	18.51	19.52	23.56
3/16	.094	.099	.120	2 3/4	20.31	21.42	25.86
1/4	.168	.177	.214	2 7/8	22.20	23.41	28.27
5/16	.262	.277	.334	3	24.17	25.50	30.78
3/8	.378	.398	.491	3 1/8	26.23	27.66	33.40
7/16	.514	.542	.655	3 1/4	28.37	29.92	36.12
1/2	.671	.708	.855	3 3/8	30.59	32.27	38.95
9/16	.850	.896	1.082	3 1/2	32.90	34.70	41.89
5/8	1.049	1.107	1.336	3 5/8	35.29	37.23	44.94
11/16	1.270	1.339	1.616	3 3/4	37.77	39.84	48.09
3/4	1.511	1.594	1.924	3 7/8	40.33	42.54	51.35
13/16	1.773	1.870	2.258	4	42.97	45.33	54.72
7/8	2.056	2.169	2.618	4 1/4	48.51	51.17	61.77
15/16	2.361	2.490	3.006	4 1/2	54.39	57.37	69.25
1	2.686	2.833	3.420	4 3/4	60.60	63.92	77.16
1 1/8	3.399	3.585	4.328	5	67.15	70.83	85.50
1 1/4	4.197	4.427	5.344	5 1/4	74.03	78.08	94.26
1 3/8	5.078	5.356	6.466	5 1/2	81.25	85.70	103.45
1 1/2	6.044	6.374	7.695	5 3/4	88.80	93.67	113.07
1 5/8	7.093	7.481	9.031	6	96.69	101.99	123.12
1 3/4	8.226	8.674	10.474	7	131.61	138.82	167.58
1 7/8	9.443	9.960	12.023	8	171.90	181.32	218.88
2	10.744	11.332	13.680	9	217.57	229.48	277.02
2 1/8	12.129	12.793	15.443	10	268.60	283.31	342.00
2 1/4	13.598	14.343	17.314	11	325.01	342.80	413.82
2 3/8	15.151	15.981	19.291	12	386.79	407.97	492.48

PROPORTIONATE WEIGHT OF CASTINGS TO WEIGHT OF WOOD PATTERNS

A Pattern Weighing One Pound, Made of (Less Weight of Core Prints)	Cast Iron	Brass	Copper	Bronze	Bell Metal	Zinc
Pine or Fir	16	15.8	16.7	16.3	17.1	13.5
Oak	9	10.1	10.4	10.4	10.9	8.6
Beech	9.7	10.9	11.4	11.3	11.9	9.1
Linden	13.4	15.1	16.7	15.5	16.3	12.9
Pear	10.2	11.5	11.9	11.8	12.4	9.8
Birch	10.6	11.9	12.3	12.2	12.9	10.2
Alder	12.8	14.3	14.9	14.7	15.5	12.2
Mahogany	11.7	13.2	13.7	13.5	14.2	11.2
Brass	0.85	0.95	0.99	0.98	1.0	0.81

ALLOWANCES FOR FITS IN AUTOMOBILE CONSTRUCTION

Fits in automobile construction can be divided into,

FORCE FITS.

To be used in parts where disassembling will hardly be required, and which are assembled by means of hydraulic or screw presses, or when hot

DRIVING FITS.

To be used in parts where close adherence is required, but which must be assembled and disassembled with no other help than an ordinary hammer, such as flywheels, gear wheels, ball-bearing inner races, etc.

PUSH FITS.

To be used in parts without relative motion in actual work but which must have sufficient freedom to be assembled by hand; such as bolts, slip joints, ball-bearing outer races, etc.

RUNNING FITS.

To be used in parts possessed of relative motion in normal running, these can be subdivided into,

Easy Fits; where great freedom of running is required with possibility of scant lubrication, such as valve guides, control connections, clutch shafts, etc

Close Fits; to be used in all high-speed work and especially the engine and transmission

Fine Fits; to be used in parts where great accuracy is required or where, while the motion is slight the stresses are of an alternating or vibratory nature, such as connecting rod small ends, steering connections etc; efficient lubrication must be provided if the motion is frequently recurring

Fit Allowances

In the allowances given in the following the expansion of metals when of different nature or exposed to heat in a different degree, such as is the case in some parts of engine construction, has not been taken into account.

ALLOWANCE OVER NOMINAL DIAMETER FOR FORCE FITS

Nominal diameter	½"	1"	2"	3"
Maximum "	0 50100	1 00200	2 00400	3 00600
Minimum "	0.50050	1 00150	2 00300	3 00450

ALLOWANCE OVER NOMINAL DIAMETER FOR DRIVING FITS

Nominal diameter	½"	1"	2"	3"
Maximum "	0.50050	1.00100	1 00175	1 00250
Minimum "	0.50025	1 00075	1 00100	1 00150

ALLOWANCE BELOW NOMINAL DIAMETER FOR PUSH FITS

Nominal diameter	½"	1"	2"	3"
Maximum "	0.49975	0 99950	1.99900	2 99850
Minimum "	0.49925	0.99900	1 99850	2.99800

ALLOWANCE BELOW NOMINAL DIAMETER FOR RUNNING FITS

EASY FITS

Nominal diameter	½"	1"	2"	3"
Maximum "	0.49900	0 99875	1 99825	2.99800
Minimum "	0.49800	0.99725	1.99650	2.99575

CLOSE FITS

Nominal diameter	½"	1"	2"	3"
Maximum "	0 59925	0.99900	1 99875	2.99850
Minimum "	0.59875	0.99800	1.99750	2 99700

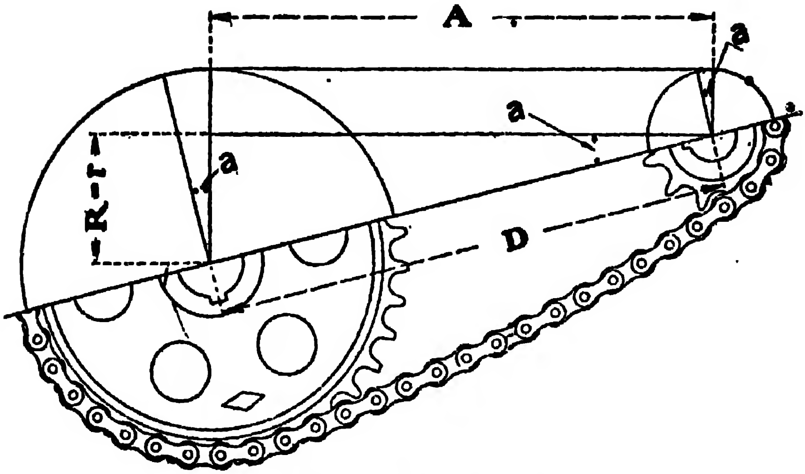
FINE FITS

Nominal diameter	½"	1"	2"	3"
Maximum "	0.59950	0.99925	1.99925	2.99900
Minimum "	0.59925	0.99875	1.99850	2.99800

For intermediate dimensions comparison between the size immediately below and that immediately above will give the safe allowances in each case.

FORMULA FOR CALCULATING LENGTH OF CHAIN

(DIAMOND CHAIN AND MFG. CO.)



(All Dimensions in Inches)

D = Distance between centers.
A = Distance between limits of contact.
R = Pitch radius of large sprocket.
r = Pitch radius of small sprocket.
N = No. of teeth on large sprocket.
n = No. of teeth on small sprocket.
P = Pitch of chain and sprockets.
$180° + 2\alpha$ = Angle of contact—large sprocket.
$180° + 2\alpha$ = Angle of contact—small sprocket.

$$\alpha = Sin^{1}\,\frac{R - r}{D}$$

$$A = D\ Cos\ \alpha$$

Total length of chain.

$$L = \frac{180 + 2\alpha}{360}\,NP + \frac{180 - 2\alpha}{360}\,nP + 2D\,Cos\,\alpha$$

Engine Lathe Gearing for Cutting Threads

Refer to the screw cutting table and see what number of turns to an inch is cut with equal gears. This number is the number of turns to an inch that we assume the lead screw has, no matter what its real number of turns to an inch is.

Simple Gearing.

Write the number of turns to an inch of the lead screw above a line, and the number of turns to an inch of the screw to be threaded below the line, thus expressing the ratio in the form of a fraction, the lead screw being the numerator and screw to be threaded the denominator. Now find an equal fraction in terms that represent numbers of teeth in available gears. The numerator of this new fraction will be the spindle or stud gear and the denominator the lead screw gear The new fraction is usually found by multiplying the numerator and denominatar of the first fraction by the same number.

EXAMPLE—Required to cut a screw having 11½ threads per inch. We find on the index that 48 to 48 cuts 4 threads per inch then $\frac{4}{11\frac{1}{2}} \times \frac{6}{6} = \frac{24}{69}$

Put the 24 tooth gear on the stud and the 69 tooth gear on the lead screw to cut 11½ threads per inch.

Any multiplier may be used to obtain gears that are available.

Compound Gearing.

Write the number of turns to an inch of the lead screw as the numerator of a fraction and the turns of the screw to be threaded as the denominator.

Factor this fraction into an equal compound fraction.

Change the terms of this compound fraction either by multiplying or dividing into another equal compound fraction whose terms represent numbers of teeth in available gears.

Then the two terms in the numerator represent the number of teeth in the gears to be used as drivers and those in the denominator the gears to be used as driven gears.

EXAMPLE—Required to cut a screw having 3¼ inches lead or $\frac{4}{13}$ turns to an inch. Lead screw is 1½ inches lead or ⅔ turns to an inch.

$$\frac{2}{3} \div \frac{4}{13} = \frac{2 \times 13}{3 \times 4} = \frac{2 \times 13}{1 \times 12}$$

Multiply numerator and demoninator by 5. $\frac{2 \times (13 \times 5)}{1 \times (12 \times 5)} = \frac{2 \times 65}{1 \times 60}$

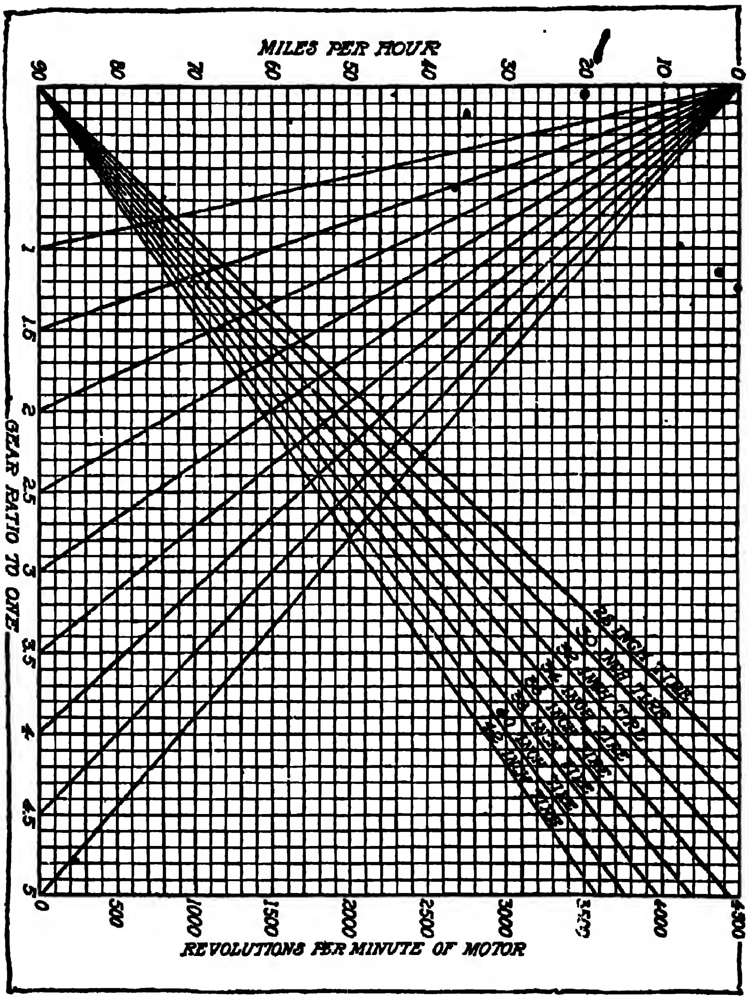
Multiply numerator and denominator by 24. $\frac{(24 \times 2) \times 65}{(24 \times 1) \times 60} = \frac{48 \times 65}{24 \times 60}$

The 48 tooth and 65 tooth gears will be the drivers and the 24 tooth and 60 tooth gears the driven.

Any multiplier may be used to obtain gears that are available.

HOW TO USE CHART OF GEAR RATIOS, TIRE SIZES AND CRANKSHAFT REVOLUTIONS PER MINUTE

Given the miles per hour, gear ratio, and tire sizes and the revolutions of a crankshaft per minute: For illustration, suppose the car is traveling at 80 miles per hour with 34-inch tires and a gear ratio of 1.5 to 1. From the figure 80 move right to the intersection of the gear ratio line designed as 1.5. From this point move up to the diagonal of 34 inches. From this point move right to

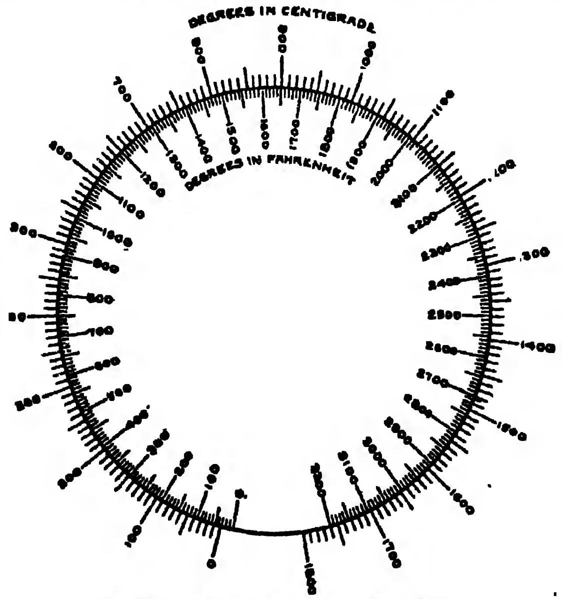


the margin where the revolutions of the crankshaft speed per minute are shown; 1,200 in this case. Given the crankshaft revolutions per minute, the tire diameters and miles per hour, find the gear ratio. Supposing the motor is turning over at 1,000 revolutions per minute, that 42-inch tires are used, and the car is traveling at 50 miles per hour. Go left from the 1,000 on the right margin until the intersection of the 42-inch tire-size line. From this point go

up to the intersection of the 50-mile-per-hour horizontal line. The intersection of this line also cuts the gear ratio of 2.7 line, which is the gear ratio employed.

Given crankshaft revolutions per minute, size of tires and gear ratio, in order to find miles per hour, proceed as follows: Go left from crankshaft speed—say 1,000 revolutions per minute—to tire size—say 28-inch. From this point go up or down to intersection of gear ratio line—say 1.5. Then go left to 55 miles per hour. If we have given crankshaft speed in revolutions per minute, miles per hour and gear ratio, the tire sizes may be obtained by going left from crankshaft speed to the intersection of the gear ratio line and thence up or down to the miles per hour, which point will mark the intersection of the required tire diameter.

COMPARATIVE SCALE — Fahrenheit & Centigrade Thermometers



TEMPERATURE CONVERSION FACTORS

	Boiling point of water at sea level
Fahrenheit thermometer..	212 degrees
Centigrade thermometer..	... 100 degrees
Reaumur thermometer ...	.. 80 degrees

Degrees Fahrenheit $= \frac{\text{Degrees Centigrade} \times 9}{5} + 32 = \frac{\text{Degrees Reaumur} \times 9}{4} + 32$

Degrees Centigrade $= \frac{(\text{Degrees Fahrenheit} - 32) \times 5}{9} = \text{Degrees Re}$

Degrees Reaumur $= \frac{\text{Degrees Centigrade} \times 4}{5} = \frac{(\text{Degrees Fahrenheit} - 32) \times 4}{9}$

TIME PER MILE EXPRESSED IN MILES PER HOUR

Time for one mile Min.	Sec.		Miles Per hour	Time for one mile Min.	Sec.		Miles Per hour	Time for one mile Min.	Sec.		Miles Per hour
0	36	=	100.00	1	12	=	50.00	1	47	=	33.64
0	37	=	97.30	1	13	=	49.31	1	48	=	33.33
0	38	=	94.74	1	14	=	48.65	1	49	=	33.03
0	39	=	92.31	1	15	=	48.00	1	50	=	32.72
0	40	=	90.00	1	16	=	47.37	1	51	=	32.43
0	41	=	87.80	1	17	=	46.75	1	52	=	32.14
0	42	=	85.71	1	18	=	46.15	1	53	=	31.86
0	43	=	83.72	1	19	=	45.57	1	54	=	31.58
0	44	=	81.82	1	20	=	45.00	1	55	=	31.30
0	45	=	80.00	1	21	=	44.44	1	56	=	31.03
0	46	=	78.26	1	22	=	43.90	1	57	=	30.77
0	47	=	76 60	1	23	=	43.37	1	58	=	30.50
0	48	=	75.00	1	24	=	42.36	1	59	=	30.25
0	49	=	73.47	1	25	=	42.35	2	0	=	30.00
0	50	=	72.00	1	26	=	41.86	2	3	=	29.26
0	51	=	70 59	1	27	=	41.38	2	6	=	28.57
0	52	=	69.23	1	28	=	40.91	2	9	=	27.90
0	53	=	67.92	1	28	=	40.91	2	9	=	27.90
0	54	=	66.67	1	29	=	40.45	2	12	=	27.27
0	55	=	65.45	1	30	=	40.00	2	15	=	26.66
0	56	=	64.29	1	31	=	39.56	2	18	=	26.08
0	57	=	63.16	1	32	=	39.13	2	21	=	25.53
0	58	=	62.07	1	33	=	38.71	2	24	=	25.00
0	59	=	61.02	1	34	=	38.30	2	27	=	24.49
1	0	=	60.00	1	35	=	37.89	2	30	=	24.00
1	1	=	59.02	1	36	=	37.50	2	33	=	23.53
1	2	=	58.06	1	37	=	37.11	2	36	=	23.07
1	3	=	57.14	1	38	=	36.73	2	39	=	22.64
1	4	=	56.25	1	39	=	36.36	2	42	=	22.22
1	5	=	55.38	1	40	=	36.00	2	45	=	21.81
1	6	=	54.55	1	41	=	35.64	2	48	=	21.42
1	7	=	53.73	1	42	=	35.29	2	51	=	21.05
1	8	=	52.94	1	43	=	34.95	2	54	=	20.69
1	9	=	52.17	1	44	=	34.61	3	0	=	20.00
1	10	=	51.42	1	45	=	34.28	..	..		....
1	11	=	50.70	1	46	=	33.96	..	...		....

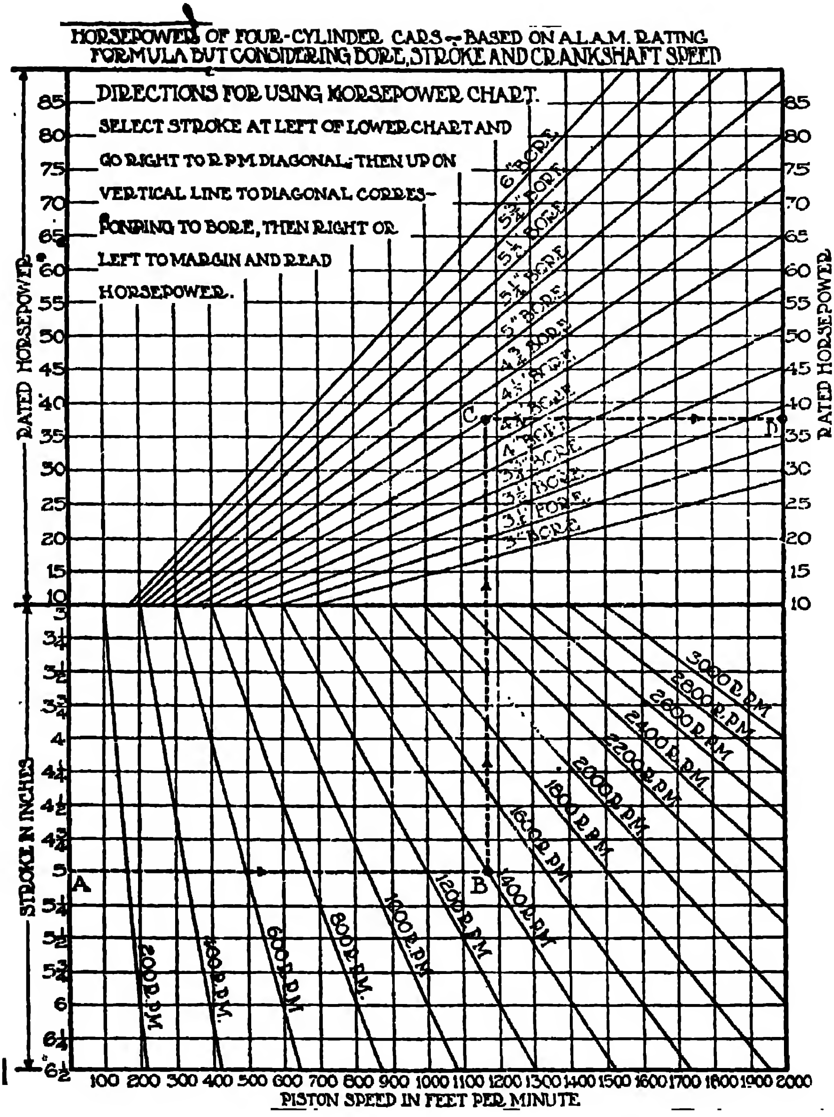
ENGLISH AND METRIC SPEED EQUIVALENTS

To obtain velocity in feet per second multiply the speed in miles per hour by 1.466+

Velocity ft. per sec.=Miles per hour x 1.466+

One mile per hour=1.466 ft. per second=88 ft. per minute=0.447 meters per second=26.8 metres per minute.

1 Km. per hour=0.914 metres per second=54.9 ft. per minute=0.624 mi. per hour.


HORSEPOWER OF FOUR-CYLINDER CARS — BASED ON A.L.A.M. RATING FORMULA BUT CONSIDERING BORE, STROKE AND CRANKSHAFT SPEED
DIRECTIONS FOR USING HORSEPOWER CHART.
SELECT STROKE AT LEFT OF LOWER CHART AND GO RIGHT TO R.P.M. DIAGONAL; THEN UP ON VERTICAL LINE TO DIAGONAL CORRESPONDING TO BORE, THEN RIGHT OR LEFT TO MARGIN AND READ HORSEPOWER.
RATED HORSEPOWER
STROKE IN INCHES
PISTON SPEED IN FEET PER MINUTE
6" BORE
5¾" BORE
5½" BORE
5¼" BORE
5" BORE
4¾" BORE
4½" BORE
4¼" BORE
4" BORE
3¾" BORE
3½" BORE
3¼" BORE
3" BORE
200 R.P.M.
400 R.P.M.
600 R.P.M.
800 R.P.M.
1000 R.P.M.
1200 R.P.M.
1400 R.P.M.
1600 R.P.M.
1800 R.P.M.
2000 R.P.M.
2200 R.P.M.
2400 R.P.M.
2600 R.P.M.
2800 R.P.M.
3000 R.P.M.
A
B
C
D
100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000

APPROXIMATE HORSEPOWER OF FOUR-CYCLE AUTOMOBILE ENGINES*

Table of Constants for Variable Speeds and Strokes

Stroke in Ins.	Revolutions per Minute of Motor														
	500	550	600	650	700	750	800	850	900	950	1,000	1,050	1,100	1,150	1,200
2.00	0.89	.098	.107	.116	.124	.134	.142	.153	.161	.169	.178	.187	.196	.205	.214
2.25	.100	.110	.120	.130	.140	.151	.160	.171	.181	.190	.200	.210	.220	.231	.24[illegible]
2.50	.112	.125	.133	.145	.156	.167	.176	.189	.201	.212	.223	.233	.245	.257	.268
2.75	.123	.135	.146	.159	.172	.184	.196	.208	.221	.233	.245	.256	270	.282	.295
3.00	.134	.147	.160	.174	.187	.201	.214	.227	.241	.254	.267	.279	.294	.308	.322
3.25	.145	.158	.173	.188	.203	.219	.232	.246	.261	.275	.289	.303	.319	.333	.349
3.50	.156	.173	.186	.203	.218	.234	.250	.265	.281	.296	.312	.326	.343	.359	.375
3.75	.167	.184	.200	.218	.234	.252	.266	.284	.301	.317	.334	.349	.368	.385	.401
4.00	.178	196	.214	.232	.249	.268	.285	.303	.321	.339	.356	.373	.392	.411	.429
4.25	.189	.208	.227	.246	.264	.285	.303	.322	.341	.360	.378	.396	.416	.436	.456
4.50	.200	.220	.240	.261	.280	.305	.321	.341	.361	381	.400	.419	.441	.461	.485
4.75	.212	.233	.253	.275	.295	.319	.339	.360	.381	.402	.423	.443	.466	.486	.509
5.00	.223	.245	.266	.290	312	.335	.357	.379	.401	423	445	.466	.491	.512	.536
5.25	.234	.257	.279	.304	.327	.351	.375	.398	.421	.444	.467	.490	.515	.538	.563
5.50	.245	.270	.293	.318	.343	.368	.393	.417	.441	.465	.489	.513	.540	.564	.590
5.75	.258	.282	.307	.332	.369	.385	.410	.436	461	.486	.512	.536	.564	.589	.616
6.00	.268	.294	.320	.348	.375	.402	.428	.455	.481	.508	535	.559	.589	.615	.643

Bore in Ins.	Square of Bore
2.00	4.00
2.25	5.06
2.50	6.25
2.75	7.55
3.00	9.00
3.25	10.56
3.50	12.25
3.75	14.05
4.00	16.00
4.25	18.05
4.50	20.20
4.75	22.55
5.00	25.00
5.25	27.50
5.50	30.20
5.75	33.05
6.00	36.00

Rule:—Multiply number to right of bore by number in upper table at intersection of proper R.P.M. and stroke columns.

Example:—Find approximate horsepower developed by motor having 4.25" bore and 5" stroke at 800 revolutions per minute.

Under 4.25 bore we find 18.05.

At intersection of 5" stroke line and 800 R.P.M. column in upper table we find .357.

The product of these numbers gives the horsepower, thus:

Approximate horsepower = 18.05 × .357 = 6.45 H.P.

These figures have been computed for the average M.E.P. as found in the ordinary motor car engine, but of course will vary with increase or decrease in compression and with different mechanical efficiencies.

*For multi-cylinder engines, multiply by number of cylinders. Above formula gives H.P. for only one cylinder.

D = Diameter of cylinder in *inches*. L = Stroke of piston in *inches*. R = Revolutions per minute of crank shaft. n = Number of cylinders.

Authority for Formula	Factors Used	Constant or Divisor
Roberts. Gas.	$D^2 \times L \times R \times n$	14000
Roberts. Gasoline.	$D^2 \times L \times R \times n$	13500
American Power Boat Association.*	$D^2 \times n$	$\frac{1\ 65}{7854} = 2.1008$
Same for less than 6 inches stroke.	$D^2 \times L \times n$	$\frac{12 \times .85}{\times\ 7854} = 12.987$

*The above are for automobile racing boat engines: for others the rating is taken as two-thirds of the above formulas. For engines having a displacer cylinder or cylinders the above rating is increased in the ratio that the displacer piston's displacement bears to that of the working cylinders.

INDICATED HORSEPOWER

On account of the great difficulty of securing good indicator cards at the high-piston and rotative speeds of automobile motors this is very little employed. The manograph which is employed for obtaining cards or diagrams from high-speed motors, as a general thing does not have an equal pressure scale and therefore does not readily lend itself to the accurate determination of I. H. P.

The indicated H. P. may of course be determined approximately by assuming a certain mechanical efficiency for the motor under consideration. This varies from as high as 90 per cent. in some cases to lower than 70 per cent. in others; the average would probably be not far from 80 per cent.

The formula for I. H. P., the bore and stroke being known as well as the R. P. M. and the mean effective pressure, is,

$$\frac{D^2 \times L \times R.P.M. \times n \times M.E.P.}{\frac{33{,}000. \times 12 \times 2}{.7854}} = I.H.P. \text{ (for 4-cycle).}$$

This constant equals 550,000 and the formula becomes $\frac{D^2 \times L \times n \times M.E.P. \times R.}{550{,}000.}$

The constant for 2-cycle is 275,000.

A formula which is given by Grover for the mean effective pressure, the compression being known, is as follows:

$$M.E.P. = 2C - 0.01\ C^2$$

C = Compression pressure above atmosphere in pounds per square inch.

This formula does not hold good for compression pressures over 100 pounds per square inch above atmosphere. Comparatively recent data seems to prove the reliability, of this formula, also the fact, which Grover points out, that under favorable conditions, the values given by this formula may be slightly exceeded. Tests with higher pressures than 100 pounds show that the M. E. P. tends to remain at 100 pounds per square inch.

The compression pressure may be obtained by some form of gauge, the ignition for that cylinder being cut off, or in case the volume of the explosion chamber is known it may be obtained from the formula.

$PV^{1.3}$ = Constant. P being the absolute pressure.

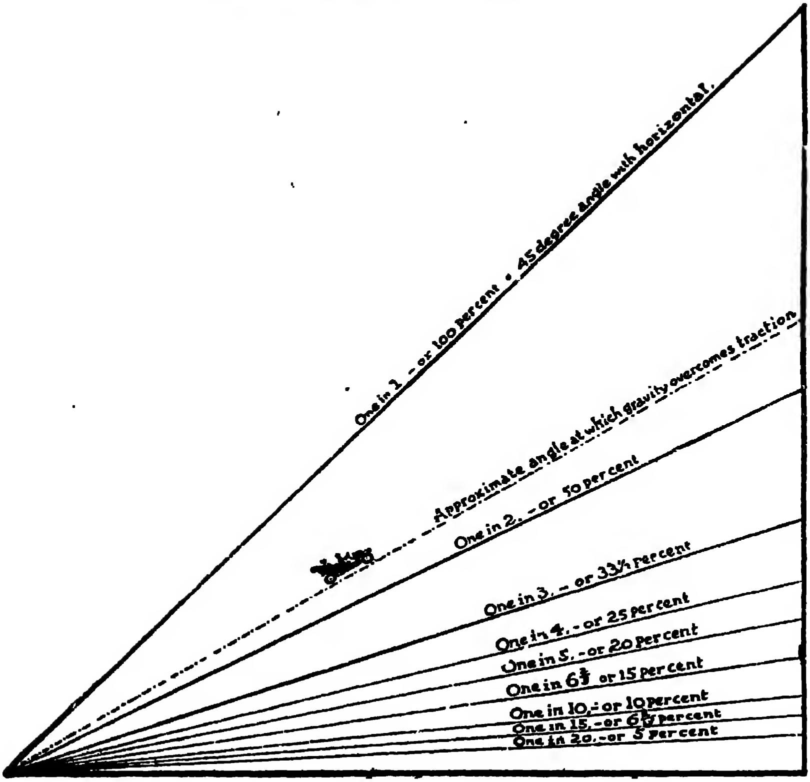
V being taken in the one case as the volume of the combustion chamber and in the other as the above plus the piston displacement. P being in one case atmospheric pressure and in the other the absolute compression pressure. Of course for C in Grover's formula the assumed atmospheric pressure should be subtracted from the result obtained by this formula.

COMPRESSION PRESSURE WITH DIFFERENT CYLINDER CLEARANCES

Cylinder Clearance, in Per Cent. of Piston Displacement	Mechanical Compression Ratio	Compression Pressure, Pounds per Square Inch Absolute		
		Low	Medium	High
20	6.	100	130	154
21	5.76	95	125	145
22	5.55	91	120	138
23	5.35	87	115	132
24	5.17	83	110	126
25	5.	80	105	121
26	4.85	77	101	116
27	4.70	74	97	111
28	4.57	71½	94	107
29	4.45	69	90	103
30	4.33	67	87	99
31	4.23	65	84	96
32	4.125	63	81½	93
33	4.03	61½	79	91
34	3.94	60	77	88
35	3.86	58	75	85
36	3.78	56½	73	83
37	3.70	55	71	81
38	3.63	54	69	79
39	3.56	53	67½	77
40	3.5	52	66	75

Computed by Cecil P. Poole.

MEASUREMENT OF GRADES



ILLUSTRATING METHOD OF CALCULATING GRADE PERCENTAGES

If it be assumed that the base of the triangle represents a line 1,000 feet long and that the first sloping line represents a road having a rise that brings it 50 feet above the starting point, this is figured as 50 feet in a thousand, or 5 per cent. In other words, one foot of rise for every 20 feet, but the latter instance does not mean distance actually traveled by a car in ascending such a slope, but distance measured horizontally with reference to that slope. The grade is measured by the tangent of the angle of inclination and not by its sine, so that a grade which represents 100 per cent. corresponds to an angle of inclination of but 45 degrees, and not 90 degrees, or perpendicular, as is commonly supposed. At the upper end of the next sloping line the elevation would amount to 66⅔ feet, which is equivalent to a rise of one foot for every 6⅔ feet traveled horizontally. So one in three corresponds to a 33 1-3 per cent. grade, one in two to a 50 per cent. grade, and so on until a 100 per cent. grade is reached, which, as noted, is the equivalent of a 45 degree angle.

TABLE OF GRADIENTS

GRADE		Equal to Angle of	Rise or Fall in One Mile, Feet
Per Cent	Units		
20	1 in 5	11° 19′	1056
17	1 " 6	9° 26′	880
14	1 " 7	8° 09′	754
12.5	1 " 8	7° 08′	635
11	1 " 9	6° 17′	586
10	1 " 10	5° 43′	528
9	1 " 11	5° 11′	480
8	1 " 12	4° 46′	440
7.75	1 " 13	4° 24′	406
7	1 " 14	4° 05′	337
6.5	1 " 15	3° 49′	352
6.25	1 " 16	3° 35′	330
6	1 " 17	3° 22′	310
5.5	1 " 18	3° 11′	293
5	1 " 19	3° 00′	277
5	1 " 20	2° 52′	204
4	1 " 25	2° 18′	218
3.3	1 " 30	1° 55′	155
2.8	1 " 35	1° 38′	151
2.5	1 " 40	1° 26′	132

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